Quantum Oscillator Lattice: A Unified Origin of Fundamental Constants and Fields

Juan Moreno Borrallo
(Dated: June 13, 2025)

Abstract. *This paper presents the foundational premises for a unified physical theory in which the vacuum is modeled as an elastic lattice of coupled quantum harmonic oscillators. Rather than aiming to construct a complete unified theory, our goal is to explore the consequences of a set of physically motivated assumptions and to demonstrate their consistency with established theoretical principles and dimensional relations. Within this framework, gravitational, electromagnetic, and thermo-entropic interactions are interpreted as distinct geometric deformation modes of a single symmetric field tensor $\mathcal{G}_{\mu\nu}$, and fundamental constants of nature emerge naturally from the oscillatory dynamics. We show that these assumptions lead to coherent interpretations of field sources (mass, charge, temperature) sharing a common oscillatory origin in spacetime. While non-exhaustive, our treatment lays a physically and mathematically grounded path for future development of a unified field theory anchored in quantum-elastic principles.*

"Entia non sunt multiplicanda praeter necessitatem"
— Ockham's Razor

"Padre, Señor del cielo y de la tierra, te doy gracias porque has ocultado todo esto a los sabios y entendidos y se lo has revelado a los que son como niños."
— Matthew 11:25

I. INTRODUCTION

The quest for a unified theoretical framework capable of describing all fundamental interactions from a common origin remains a central theme in contemporary physics [1]. Despite the tremendous success of the Standard Model of particle physics in unifying electromagnetic, weak and strong forces [2], and of General Relativity (GR) in geometrizing gravity [3, 4], a conceptual schism persists between the quantum field theories (QFTs) of the former and the geometric description of the latter [5]. Moreover, observational puzzles such as dark energy and dark matter [6–8], together with the inability to quantize gravity in a conventional QFT framework [9], underscore the need for a deeper structure underlying both regimes.

Thermodynamic and emergent-gravity approaches have hinted at such a structure. Jacobson's derivation of Einstein's equations from local entropy balance [10], Verlinde's entropic gravity proposal [11], and the striking analogies between black-hole thermodynamics and vacuum fluctuations [12] point toward an intimate link between entropy, quantum vacuum dynamics, and spacetime geometry. Likewise, the shared inverse–square dependence of Newton's law and Coulomb's law suggests that disparate forces may be just different manifestations of a single underlying field.

In this work, we explore the hypothesis that the quantum vacuum itself—spacetime at its most fundamental level—constitutes an active medium whose local excitations give rise to all observed fields and particles. Guided by the empirical fact that both electromagnetic radiation and gravitational waves propagate as oscillatory disturbances [13], and given that harmonic oscillators occurring in a number distinct physical realities are equivalent -in the sense that their mathematical models are identical- [14] we postulate that this unified field must be inherently oscillatory, and that dimensionality of -within human perception- disparate physical sourcing phenomena, such as mass, charge, temperature, etc., collapse into a single dimensionality -spacetime- as the source of this unified field.

As a result, within this framework, conventional distinctions among electromagnetic, gravitational and thermodynamic phenomena dissolve: they emerge as different vibrational, shear or torsional modes of the same quantum harmonic oscillator's lattice. Fundamental constants of nature cease to be arbitrary uncorrelated inputs, and become effective parameters describing the coupling strength or resonant behavior of the vacuum. By mapping vacuum dynamics to mechanical and electrical oscillatory phenomena, we derive novel relations among these constants, and reinterpret physical quantities—mass, charge, temperature—as localized topological excitations in the underlying oscillator network.

An important clarification is that we do not attempt to construct a full and complete unified theory. Rather, we propose and explore a set of physically motivated postulates, and analyze how far these assumptions can go in explaining the emergence of known fields and constants, and in revealing coherent dimensional structures. The aim of this paper is to evaluate the internal consistency, physical plausibility, and predictive coherence of these assumptions—not to deliver a fully quantized or dynamically complete theory. In this sense, the present work should be seen as a conceptual and dimensional groundwork for future unified field models.

Part I: General Framework

II. THE COMMON FIELD AS AN ENSEMBLE OF QUANTUM HARMONIC OSCILLATORS

A. Harmonic Oscillator Equations in Mechanical and Electrical Systems

Consider a damped mass-spring system:

$$m\ddot{x} + b\dot{x} + kx = 0, \tag{1}$$

where m is mass, b is the damping coefficient, and k is the spring constant. The corresponding Lagrangian (neglecting dissipation) is:

$$\mathcal{L}_{\text{mech}} = \frac{1}{2}m\dot{x}^2 - \frac{1}{2}kx^2.$$

On the other hand, in an RLC circuit, let $q(t)$ be the charge on the capacitor:

$$L\ddot{q} + R\dot{q} + \frac{1}{C}q = 0, \tag{2}$$

where L is inductance, R is resistance, and C is capacitance. An equivalent Lagrangian (again omitting dissipation) reads:

$$\mathcal{L}_{\text{elec}} = \frac{1}{2}L\dot{q}^2 - \frac{1}{2C}q^2.$$

In developing a unified field theory rooted in oscillatory dynamics, it becomes essential to identify a consistent dimensional framework that naturally connects mechanical and electrical systems. Classical analogies between mass-spring and RLC oscillators reveal deep structural equivalences among their parameters: mass $m \leftrightarrow L$ (inductance), damping $b \leftrightarrow R$ (resistance), and stiffness $k \leftrightarrow 1/C$ (inverse capacitance). These analogies go beyond formal resemblance—they reflect identical structures governing the system's evolution, and a common underlying substrate.

To reflect this symmetry at the dimensional level, we postulate that such correspondences are not merely mathematical, but encode a deeper physical equivalence. In particular, we adopt as our first fundamental postulate that, within the unified field framework, *mechanical and electromagnetic inertia share the same dimensional character*. That is:

$$[\text{Inductance}] \equiv [\text{Mass}].$$

This equivalence does not imply that mass and inductance are equal in any conventional system, but rather that they play *isomorphic roles* within the elastic vacuum model: both represent resistance to changes in oscillatory motion—mechanical or electromagnetic—and encode the same form of reactive inertia under field excitation. Such a postulate is thus not arbitrary, but a natural requirement of modal unification, guiding the redefinition of all fundamental units from first principles.

Taking the SI units of inductance L as $[ML^2I^{-2}T^{-2}]$, this postulate leads directly to:

$$[M] \equiv [ML^2I^{-2}T^{-2}],$$

For dimensional consistency, this postulate requires that the combination $[L^2I^{-2}T^{-2}]$ must be dimensionless. Solving for the dimension of current $[I]$ yields:

$$[I^2] \equiv [L^2T^{-2}] \implies \boxed{[I] \equiv [LT^{-1}]} \tag{3}$$

This result, stemming directly from our initial postulate, implies that electric current within this unified picture acquires the dimensions of velocity. The consequences of this dimensional assignment will be explored throughout this work.

As a sanity check, the resistance R in an RLC circuit is analogous to the damping coefficient b in a mechanical oscillator. Establishing the dimensional equivalence between them, we find that:

$$[MT^{-1}] \equiv [ML^2T^{-3}I^{-2}],$$

which implies that $[L^2I^{-2}T^{-2}]$ becomes dimensionless, as we had obtained just before, and which leads to the dimensionality found for I.

B. Redefining the Ampere as a Velocity

In standard SI practice, the ampere (A) is treated as an independent base unit, separate from mass, length, and time. However, in the dimensional framework of our unified theory—where mass, length, time, and charge share a common geometric substrate—this separation becomes unnecessary. Motivated by the structural analogies between mechanical and electromagnetic oscillators, and following our first postulate (II A), we adopt the convention:

$$[I] \equiv \frac{[L]}{[T]}, \tag{4}$$

thereby equating the ampere to a fundamental velocity scale. This identification is not arbitrary: it emerges naturally when current is reinterpreted as an excitation velocity within the vacuum's oscillator network.

1. No Change in Physical Predictions

Redefining the ampere in this manner does not alter any physical laws or measurable outcomes. Rather, this shift reorganizes the dimensional bookkeeping:

1. *Under the conventional SI system*, current I constitutes an independent dimension, complicating the structure of electromagnetic quantities (e.g., impedance, field strength, permittivity).
2. *Within our unified framework*, I is expressed as $\frac{L}{T}$, simplifying the dimensional equivalences to a common ground in spacetime.

Thus, this redefinition introduces no empirical contradiction—only a reformulation that is internally consistent and fully compatible with traditional measurements.

2. Geometric and Physical Interpretation

This shift reveals a deeper physical insight: electric current is not merely a rate of charge transfer, but a manifestation of *spacetime flow*—a directed, quantized deformation of the elastic vacuum. The ampere, in this light, becomes the natural unit of deformation rate within the unified field, particularly along radial (electromagnetic) modes of the symmetric tensor $\mathcal{G}_{\mu\nu}$ that we will postulate later on (X).

This reinterpretation also supports a conceptual bridge between the source terms in gravitational and electromagnetic field equations. In this sense, mass and charge both source curvature by altering the local flow of the vacuum, and their associated "currents" (gravitational and electric flow) emerge as conjugate expressions of the same geometro-dynamic principle.

3. Toward Unified Source Terms

As a result, this dimensional identification sets the stage for a unified treatment of source terms across field equations, and invites a reinterpretation of current as a *dynamical field generator*, not merely a charge derivative. Redefining the ampere as velocity not only simplifies the dimensional landscape, but also aligns electromagnetism with the spacetime symmetries that govern motion and gravity, contributing to the internal coherence of the unified field model.

C. Dimensional Collapse and Space–Time Equivalence in the Unified Field

The striking structural symmetry between Newton's Law of Gravitation and Coulomb's Law

$$F = G\frac{m_1 m_2}{r^2}, \quad F = K\frac{q_1 q_2}{r^2}.$$

provides strong motivation for exploring an even deeper connection. Within our developing framework, and following the physical interpretation of current stemming from our first postulate, we naturally introduce a second key postulate: the dimensional equivalence of the coupling constants G and K_e. This postulate embodies the already stated hypothesis that the fundamental sources, mass and charge, play analogous roles governed by similar principles within the unified field structure (II B 2), reflected dimensionally in their respective force constants.

Let us rigorously derive the consequences of this postulate combined with our previous findings. The conventional SI dimensions are:

$$[G] = [M^{-1}L^3T^{-2}], \quad [K_e] = [ML^3T^{-4}I^{-2}].$$

Setting $[G] \equiv [K_e]$, we obtain:

$$[M^{-1}L^3T^{-2}] \equiv [ML^3T^{-4}I^{-2}].$$

Rearranging for $[M]$, and recalling that within the unified framework we have established $[I] \equiv [LT^{-1}]$ (4), we substitute I^{-2} as:

$$[M^{-1}L^3T^{-2}] \equiv [ML^3T^{-4}(L^{-2}T^2)].$$

Simplifying, we find:

$$\begin{aligned} &[M^{-1}L^3T^{-2}] \equiv [MLT^{-2}] \rightarrow \\ &[M^{-1}L^3] \equiv [ML] \rightarrow \\ &[L^2] \equiv [M^2] \rightarrow \\ &\boxed{[M] \equiv [L]} \end{aligned} \tag{5}$$

This outcome, contingent on the postulates $[Mass] \equiv [Inductance]$ and $[G] \equiv [K_e]$, signifies that mass and length share the same fundamental dimension within this theoretical structure. From this result and the previous ones, we can substitute $[M]$ and $[I]$ in the previous equivalence $[MT^{-1}] \equiv [ML^2T^{-3}I^{-2}]$, to get that $[T^{-4}L^4]$ becomes dimensionless; which, in turn, implies that we have reached the fundamental equivalence

$$\boxed{[M] \equiv [L] \equiv [T]} \tag{6}$$

This result establishes a profound conclusion: *mass, length and time are fundamentally equivalent in the common unified field.* And this equivalence leads to a natural collapse of dimensions -as we will see-, implying that the evolution of the universe should be understood in terms of oscillatory interactions where mass-energy, length and time emerge as manifestations of a unified, underlying geometric structure.

D. The dimensions of sources and universal constants in the unified field framework

We can now establish the dimensions of the most important constants and physical phenomena that we will consider throughout this Paper, once we apply the fundamental equivalence (6):

- **Mass:** As already stated, we have $[M] \equiv [T] \equiv [L]$.
- **Energy:** As per Einstein's equation $E = mc^2$, it has dimensions $[L] \equiv [T]$.
- **Charge:** As $[Q] = [I \cdot T]$ and we have that $[I] \equiv [1]$, it has dimensions $[L] \equiv [T]$.
- **Temperature:** As $k_B T$ has dimensions of energy, and k_B becomes dimensionless (IV C 3), it has the same dimensions of energy, and thus it has dimensions $[L] \equiv [T]$.
- **Current:** Becomes dimensionless, as we have that $[I] \equiv [LT^{-1}] \equiv [1]$
- **Resistance:** Becomes dimensionless, as $[R] = [MT^{-1}] \equiv [ML^2T^{-3}I^{-2}] \equiv [1]$
- **Voltage:** By Ohm's law, we have that $V = I \cdot R$. As both I and R are dimensionless, voltage V becomes dimensionless too.
- **Power:** As we have that $P = V \cdot I$, and $P = \frac{V^2}{R}$, power P becomes dimensionless too.
- **The "speed of light" c:** As any velocity with dimensions $[LT^{-1}]$, it becomes dimensionless.
- **Planck's constant h:** As the quantum of action, it has dimension $[E \cdot T]$. Therefore, it has dimensions $[L^2] \equiv [T^2]$.
- **Electric permittivity ε_0:** As it has dimension $[\varepsilon_0] = [M^{-1}L^{-3}T^4I^2]$, it becomes dimensionless.
- **Magnetic permeability μ_0:** As it has dimension $[\mu_0] = [MLT^{-2}I^{-2}]$, it becomes dimensionless.
- **The gravitational constant G:** Through Newton's law, G has dimensions $[G] = [M^{-1}T^{-2}L^3]$. Thus, it becomes dimensionless.
- **Coulomb's constant K_e:** Being equal to $\frac{1}{4\pi\varepsilon_0}$, it becomes dimensionless.
- **Boltzmann's constant k_B:** From the equivalence derived in (IV C 3), it becomes dimensionless.
- **The fine-structure constant α:** By its definition, $\alpha = \frac{e^2}{2\varepsilon_0 hc}$. One can check that using the previous dimensions described, it is dimensionless, as expected.

E. Reflection on Dimensional Equivalence and Its Implications for Fundamental Units

The choice of a unit system in physics is more than a matter of convenience; it can reveal deeper structures in the relationships among physical quantities. In particular, within the context of the unified field, we formally write

$$[L] \equiv [T_{\text{ime}}] \equiv [M] \equiv [E] \equiv [Q] \equiv [T_{\text{emp}}], \tag{7}$$

meaning that, *within the theoretical model*, these quantities share a common dimensional basis. Strictly speaking, this does not invalidate the traditional distinction among meters, seconds, kilograms, joules, coulombs, and kelvins in everyday measurements or standard SI usage. Rather, it asserts that *when certain fundamental constants are equated and treated as direct conversion factors, one can recast these different units as numerically equivalent:*

$$1 \text{ m} \equiv 1 \text{ s} \equiv c^2 \text{ kg} \equiv 1 \text{ J} \equiv 1 \text{ C} \equiv 1 \text{ K}. \tag{8}$$

This equivalence is neither arbitrary nor merely a notational trick; it reflects the idea that universal constants play the role of *natural conversion factors* between dimensions like length, time, mass, energy, charge, and temperature. In other words, once these constants are taken as fundamental geometric elements of the theory, the differences among standard SI units become a matter of labeling, rather than a manifestation of fundamentally different dimensions within the unified framework.

Hence, we do not erase the operational definitions of the meter, second, or kilogram as used in the laboratory. Rather, we embed them into a broader dimensional structure, where what appear as separate units in standard SI can be seen, at a deeper theoretical level, as different expressions of the same underlying physical reality.

Under this viewpoint, universal constants lose their "arbitrary" character. They become the metric coefficients of a generalized physical geometry—effectively the "metric" that converts one nominal unit into another. This unification thus provides a self-consistency check: if all these quantities truly emerge from the same resonant spacetime lattice, then setting them equal at the fundamental level (via the constants) should lead to a coherent, contradiction-free description of nature.

Part II: Fundamental nature and relationships of universal constants

III. CORE IDENTIFICATIONS AND INITIAL EVALUATIONS

Building on the foundational postulates and the resulting dimensional unification established in subection II C, we now summarize the basic core identifications made within this framework:

Quantum	Identification	SI Units	U. Field
Velocity v	$v = c$	$m \cdot s^{-1}$	Dimensionless
Acceleration a	$a = \frac{v}{t} = \frac{c}{1\ s}$	$m \cdot s^{-2}$	$s^{-1} \equiv m^{-1}$...
Current I	$I = v = c$	A	Dimensionless
Ang. Freq. ω_0	$\omega_0 = \frac{c}{1\,\mathrm{s}}$	s^{-1}	$s^{-1} \equiv m^{-1}$...
Inductance L	$L = \mu_0 \cdot 1\,\mathrm{m}$	H	Dimensionless
Capacitance C	$C = \varepsilon_0 \cdot 1\,\mathrm{m}$	F	Dimensionless
Spr. Const. k	$k = \frac{1}{C} = \frac{1}{\varepsilon_0 \cdot 1\,\mathrm{m}}$	F^{-1}	Dimensionless
Charge Q	$Q = e$	C	$C \equiv s \equiv m$ ...
Resistance R	$Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}$	Ω	Dimensionless
Time Const, τ	$\tau = RC = \frac{1\,\mathrm{m}}{c}$	s	$s \equiv m \equiv$ ...
Voltage V	$V = I \cdot R = \frac{1}{\varepsilon_0}$	V	Dimensionless

TABLE I. Summary of the basic mapping of fundamental constants, showing how each maps onto a mechanical or electrical analogue.

We can perform some sanity checks to evaluate the validity and impact of the above identifications.

A. First sanity check

Consider some total dissipated electromagnetic energy due to resistance. Using the Rayleigh dissipation function

$$F = \frac{1}{2} R I^2, \tag{9}$$

the instantaneous power dissipation in the system is given by:

$$P_{\mathrm{dis}}(t) = \frac{dE_{\mathrm{dis}}}{dt} = R I^2 \tag{10}$$

Substituting the defined core parameters, we have

$$P_{\mathrm{dis}}(t) = Z_0 \cdot c^2 \tag{11}$$

To determine the total energy dissipated over the characteristic time interval τ, we integrate this power dissipation from 0 to τ:

$$E_{\mathrm{dis}} = \int_0^{\tau} P_{\mathrm{dis}}(t)\, dt \tag{12}$$

Using $\tau = \frac{1\mathrm{s}}{c}$, we evaluate the integral:

$$E_{\mathrm{dis}} = Z_0 \cdot c^2 \cdot \frac{1\ s}{c} = \frac{1}{\varepsilon_0} \cdot 1\ s \tag{13}$$

The above is dimensionally consistent within the framework of the unified field, as $\left[\frac{1}{\varepsilon_0}\right] \equiv [V]$ and $1\ s \equiv 1C$. And, to explore the potential power of the framework we are developing, we can point out the following: within the unified field, the above expression admits a direct mechanical analogy with Hooke's law in its linear form, $E = -kx^2$. Note that we have identified the inverse vacuum permittivity per meter, $\frac{1}{\varepsilon_0 \cdot 1\ m}$, with an effective *stiffness* constant k of the vacuum (I) —representing its resistance to deformation or response under excitation—while we also have established that $1\ s \equiv 1$ m, which naturally corresponds to a spatial displacement x. The resulting structure, $E_{\mathrm{dis}} = kx^2 = \frac{1}{\varepsilon_0} \cdot 1$ s, underscores how the unified field behaves as an elastic medium, in which energy is linearly related to displacement via an intrinsic stiffness.

B. Second sanity check

As a second sanity check, consider the energy stored in a capacitor and inductor:

$$E_{LC} = \frac{1}{2} C V^2 + \frac{1}{2} L I^2 \tag{14}$$

and substitute:

- $C = \varepsilon_0 \cdot 1$ m is the capacitance, consistent with the definition and SI units of ε_0.
- We can apply Ohm's Law to derive $V = I \cdot R = c \cdot Z_0 = \frac{1}{\varepsilon_0}$ as some voltage,
- $I = c$ is the current within the context of the unified field.

Substituting these values yields

$$E_{LC} = \frac{1}{2}(\varepsilon_0 \cdot 1\ m) \cdot \frac{1}{\varepsilon_0^2} + \frac{1}{2} L \cdot c^2 \tag{15}$$

This discrete LC system serves as a localized analogy for the vacuum's elastic behavior. To capture this oscillatory structure in a continuous, field-theoretic setting, let $\Phi(x)$ denote a *field* -in general, it can be a multi-component scalar, vector, or tensor, but for illustrative purposes, we treat it here as a single real scalar field-. Include just the two couplings (or 'rigidities") usual for harmonic oscillatory systems. Then, one has the following *minimal* Lagrangian density:

$$\mathcal{L}(\Phi) \;=\; \frac{1}{2}\,\kappa_1 \left(\partial_t \Phi\right)^2 \;-\; \frac{1}{2}\,\kappa_2 \left(\nabla \Phi\right)^2 \tag{16}$$

Here,

- κ_1 controls the 'inertial" or kinetic response of the field mode,
- κ_2 represents the elastic/spatial rigidity of the field mode.

Note that the requirement

$$\kappa_1 = \kappa_2$$

is the very condition that makes the field equation into the Lorentz-invariant wave equation

$$\Box \Phi = 0,$$

as for any plane-wave solution

$$\Phi(t, \mathbf{x}) \propto e^{i(\omega t - \mathbf{k}\cdot\mathbf{x})}$$

this equality forces $\omega^2 = |\mathbf{k}|^2$, and one finds at every point (or on average over a cycle)

$$\tfrac{1}{2}\,\kappa_1 (\partial_t \Phi)^2 \;=\; \tfrac{1}{2}\,\kappa_2 (\nabla \Phi)^2$$

In other words, Lorentz symmetry *kinematically* guarantees that each mode carries exactly half its energy in "kinetic" form and half in "gradient" form. We may therefore adopt the usual LC-circuit equipartition

$$C\,V^2 = L\,I^2$$

We can solve (15) for the inductance L to get:

$$L = \frac{CV^2}{I^2} = \frac{1\ m}{\varepsilon_0 c^2} = \mu_0 \cdot 1\ m \tag{17}$$

Which serves as a consistency check, as our proposed quantum of inductance is indeed $\mu_0 \cdot 1\ m$ (I). And, substituting with L and calculating, we get that

$$E_{LC} = \frac{1\ m}{\varepsilon_0} = \mu_0 \cdot 1\ m \cdot c^2 = 4\pi K_e \cdot 1\ m$$

Brief note on the obtained result

The result $E_{LC} = 4\pi K_e \cdot 1$ m, as within the unified field we have that $\left[\frac{1}{\varepsilon_0}\right] = [4\pi K_e] \equiv [V]$ and $1\ m \equiv 1C$, can be interpreted as the quantum of electrostatic energy.

This expression not only confirms the internal consistency of our dimensionally collapsed framework, but also shows that *the requirement $\kappa_1 = \kappa_2$ —which ensures Lorentz invariance in the scalar field model— corresponds physically to energetic equipartition between electric and magnetic modes (or kinetic and potential modes in the oscillator analogy).*

In this view, the field equation $\Box\Phi = 0$ represents the fundamental wave dynamics of the unified vacuum, and its LC analogue illustrates how energy is stored and propagated through field excitations. We will postulate in (IX C) that each field mode that we propose (e.g. electromagnetic, gravito-entropic) can be modeled as a scalar excitation with effective rigidity κ, matched to the appropriate constant (ε_0, μ_0, G, k_B) depending on the physical context.

Thus, the scalar field model drafted above does more than reproduce known equations—it captures the essential modal structure of the symmetric fundamental tensor $\mathcal{G}_{\mu\nu}$ (X), and justifies, from energetic and variational grounds, the emergence of field equations and constants from a deeper elastic structure. In this light, the equality $\kappa_1 = \kappa_2$ becomes not a mere condition for symmetry, but a *physical principle of balance*: the propagation of deformation through the vacuum respects a universal ratio between inertial response and spatial rigidity—a signature of a fundamentally oscillatory spacetime.

C. Third sanity check

In (14), we could have naturally set $L = \mu_0 \cdot 1\ m$ and $C = \varepsilon_0 \cdot 1\ m$ as the inductance and capacitance of the system, corresponding to the magnetic and electric energy storage capacities of the vacuum. Also, we can naturally set the scaled angular frequency for the electromagnetic regime (I)

$$\omega_0 = \frac{c}{1\ s}$$

In an RLC circuit, the charge Q on the capacitor and the current I in the circuit are related through the time derivative. Specifically, the current I is the time derivative of the charge Q:

$$I(t) = \frac{dQ(t)}{dt}$$

For sinusoidal oscillations, we can express the charge Q and the current I as:

$$Q(t) = Q_0 \cos(\omega t)$$

$$I(t) = -Q_0 \cdot \omega_0 \sin(\omega t)$$

where Q_0 is the maximum charge on the capacitor.

From these equations, we can see that the peak current $I_{\max}$ (the maximum value of $I(t)$) is:

$$I_{\max} = Q_0 \cdot \omega_0$$

Then, with the equivalence $e = Q_0$ (where e is the elementary electric charge) and $\frac{c}{1\ s} = \omega_0$, we have that the maximum current of the system is given by

$$I = \frac{e \cdot c}{1\ s} \tag{18}$$

The energy stored in the electric field of a capacitor with capacitance $C = \varepsilon_0 \cdot 1\,\mathrm{m}$ and charge $Q = e$ is:

$$E_{\text{electric}} = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{e^2}{\varepsilon_0 \cdot 1\,\mathrm{m}}$$

The energy stored in the magnetic field of an inductor with inductance $L = \mu_0 \cdot 1\,\mathrm{m}$ and peak current $I = \frac{e \cdot c}{1\,\mathrm{s}}$ is:

$$E_{\text{magnetic}} = \frac{1}{2}LI^2 = \frac{1}{2}\mu_0 \cdot 1\,\mathrm{m} \cdot \left(\frac{e \cdot c}{1\,\mathrm{s}}\right)^2 = \frac{1}{2}\frac{\mu_0 e^2 c^2}{1\ m},$$

where we have applied $1\ s \equiv 1\ m$ to simplify. As a result, the total energy of the system is the sum of the electric and magnetic contributions:

$$E_{\text{total}} = E_{\text{electric}} + E_{\text{magnetic}} = \frac{1}{2}\frac{e^2}{\varepsilon_0 \cdot 1\,\mathrm{m}} + \frac{1}{2}\frac{\mu_0 e^2 c^2}{1\ m}.$$

However, since the electric and magnetic fields are dynamically coupled in the vacuum (as described by Maxwell's equations), the peak energy contributions occur simultaneously [15] [16]. This means the total energy is effectively doubled, and we have that:

$$E_{\text{total}} = \left(\frac{e^2}{\varepsilon_0 \cdot 1\,\mathrm{m}} + \frac{\mu_0 e^2 c^2}{1\ m}\right) \tag{19}$$

Substituting with the CODATA values of the fundamental constants, one gets an approximate value of $E_{\text{total}} \approx 5.75 \times 10^{-27}\ J$. This value aligns with the measurements of the vacuum energy density ρ_{vac} obtained by the Planck Collaboration in 2015 [17]. Note that, within the unified field framework, we have $1\ C \equiv 1\ kg$, so $[\rho_{vac}] = \left[\frac{E_{\text{total}}}{1\ m^3}\right]$.

Final note on the sanity checks section

The sanity checks performed underscore both the internal consistency and the potential theoretical power of the established framework. In the next section, we will show the emergence of other fundamental constants of nature from the application of traditional Laws of Physics and the already proposed core parameters.

IV. THE EMERGENCE OF FUNDAMENTAL CONSTANTS FROM TRADITIONAL PHYSICS

In this section, we present a collection of derivations of fundamental physical constants and quantities obtained through the direct application of well-established physical laws, now reinterpreted within the unified field framework developed throughout this work. These derivations serve a dual purpose: on one hand, they confirm the internal consistency of the framework by showing that classical results naturally emerge from the collapsed dimensional structure; on the other, they provide new physical insights by revealing hidden connections among constants that traditionally appeared unrelated.

The approach taken here does not discard the conventional form of physical laws such as Ampère's law, Gauss's law, Newton's law of gravitation, or thermodynamic identities, all of which remain valid and demonstrable within their respective classical domains [16, 18, 19]. Rather, it recontextualizes them under the assumption of dimensional unification, where $[M] \equiv [L] \equiv [T]$, and where constants of nature are not arbitrary scaling factors but geometric or elastic properties of the vacuum itself.

Each subsection within this part focuses on a specific law or identity and illustrates how it leads to compact expressions, derivations and relationships between constants of nature, often involving just one or two steps of algebra. This reinforces the notion that physical constants are not empirically isolated, but rather interconnected outputs of a deeper, modal-geometric structure of spacetime.

A. Modal Vacuum Actions: Scaling Regimes and the Emergence of S_{ref}, $\hbar$ and S_{th}

In the unified elastic framework, each fundamental field—gravitational, electromagnetic, and thermo-entropic (VIII)—emerges as a modal excitation of the same vacuum substrate (IX C). These excitations are characterized by distinct action densities over scaled four-dimensional volumes. We now derive the characteristic *action quantum* for each regime, showing that quantities such as a base action $S_{\rm ref}$, the Planck constant $\hbar$, and a thermo-entropic action $S_{\rm th}$ (associated to the cosmological constant Λ), arise as invariant geometric projections of the same elastic vacuum.

1. *Reference regime — gravitational mode.*

We begin by postulating a fundamental uniform Lagrangian density for the vacuum:

$$\mathcal{L}_{\rm ref} = \frac{1}{1\,{\rm m}^2} \tag{20}$$

This corresponds to the minimal areal curvature of the vacuum per unit 4-volume. In the reference gravitational regime, time and length are taken as identical units ($[L] = [T] = 1\,{\rm m}$). The four-dimensional integration domain thus becomes:

$$d^4x = 1\,{\rm m}^4 \tag{21}$$

yielding a characteristic action:

$$\mathcal{S}_{\rm ref} = \int \mathcal{L}_{\rm ref}\, d^4x = \frac{1}{1\,{\rm m}^2} \cdot 1\,{\rm m}^4 = 1\,{\rm m}^2 \equiv 1\,{\rm J}\cdot{\rm s} \tag{22}$$

This result represents the *baseline modal action* of the vacuum. Using the equivalence $1\,{\rm kg} \equiv \frac{1}{c^2}\,{\rm J}$ (derived from Einstein's fundamental equation), the gravitational action corresponds to:

$$\mathcal{S}_{\rm ref} = \frac{1\,{\rm kg}\cdot{\rm s}}{c^2}$$

Note that, theoretically, it comes naturally to construct the quantum of charge e_q as the product of the structural voltage μ_0 (30) and the structural capacitance $\varepsilon_0 \cdot 1\ m$ (I), to get that

$$e_q = \mu_0 \varepsilon_0 \cdot 1\ m = \frac{1\ m}{c^2} \tag{23}$$

As a result, using the equivalence $1\ m \equiv 1\ s$, we have that $\mathcal{S}_{\rm ref} \equiv e_q \cdot 1\ kg$, where e_q denotes the elementary electric unit in energy form.

This result shows that the elementary quantum of electric charge e_q is not merely a phenomenological constant but a direct expression of the vacuum's structural response to deformation. Consequently, the reference action $\mathcal{S}_{\rm ref} = e_q \cdot 1\,{\rm kg}$ encapsulates how a unit mass couples to the minimal quantum of curvature or twist in the vacuum substrate. This connects the emergence of charge with the elastic geometry of space, reinforcing the idea that mass, charge, and temperature are unified as different projections of the same underlying structure.

2. *Electromagnetic mode*

In the electromagnetic regime, length scale relativistically by c^2, so both the Lagrangian and volume are scaled:

$$x_{EM} = \frac{1\,{\rm m}}{c^2} \equiv e_q \quad \Rightarrow \quad \mathcal{L}_{\rm EM} = \frac{c^4}{1\,{\rm m}^2}, \quad d^4x_{EM} = \frac{1\,{\rm m}^4}{c^8}$$

Then, the action becomes:

$$\begin{aligned}\hbar = \int \mathcal{L}_{\rm EM}\, d^4x_{EM} = \frac{c^4}{1\,{\rm m}^2} \cdot \frac{1\,{\rm m}^4}{c^8} = \frac{1\,{\rm m}^2}{c^4} \\ \equiv \frac{1\,{\rm J}\cdot{\rm s}}{c^4} \approx 1.2 \times 10^{-34}\ {\rm J}\cdot{\rm s}\end{aligned} \tag{24}$$

which closely approximates the measured value of the reduced Planck constant $\hbar = 1.054 \times 10^{-34}\,{\rm J}\cdot{\rm s}$. The small numerical discrepancy (about 15%) may stem from second-order corrections due to spatial anisotropy, oscillatory coupling, or the projection geometry of the modal fields (XIII B). That is, while the lowest-order action is governed by a uniform energy density over a flat cell, real excitations involve dynamical distortions that contribute curvature and tension, modulating the exact value. These corrections could be associated with local deviations from the ideal spherical symmetry or with the full tensorial dynamics of the elastic vacuum lattice.

This derivation reinforces the idea that the Planck constant is not inserted by hand but emerges from the basic structure of the vacuum when viewed as a quantized, elastic space-time substrate. The action $\hbar$ becomes a geometric invariant of the minimal modal excitation volume.

3. *Thermo-entropic mode*

In this mode, length-time units are further scaled, yielding:

$$x_{th} = \frac{1\,{\rm m}}{c^4} \quad \Rightarrow \quad \mathcal{L}_{\rm th} = \frac{c^6}{1\,{\rm m}^2}, \quad d^4x_{th} = \frac{1\,{\rm m}^4}{c^{12}}$$

Then the action becomes:

$$S_{\rm th} = \int \mathcal{L}_{\rm th}\, d^4x_{th} = \frac{c^6}{1\,{\rm m}^2}\cdot\frac{1\,{\rm m}^4}{c^{12}} = \frac{1\,{\rm m}^2}{c^6} \equiv \frac{1\,{\rm J}\cdot{\rm s}}{c^6} \approx 1.377\times10^{-51}\ {\rm J}\cdot{\rm s} \tag{25}$$

This quantity is numerically close to the observed value of the cosmological constant $\Lambda \sim 10^{-52}\,{\rm m}^{-2}$, suggesting that the cosmological constant itself may be interpreted as the action density of a *residual modal action* projected from ultra-low frequency deformations of the vacuum (we will show that this is indeed the case (123)).

As a result, we have shown how some of the most important constants of nature arise not by empirical insertion, but as geometrically quantized projections of the same vacuum Lagrangian density over scaled modes of the same deformable elastic substrate. These results suggest that S_{ref}, $\hbar$, and S_{th} act as modal Noether invariants—emergent from distinct projections of the same elastic vacuum structure—and that what we traditionally interpret as fundamental constants of nature are, in fact, geometric integrals over scaled deformations of a single quantized substrate.

B. Vacuum impedance Z_0 and Ámpères Law

In the quasi-static regime, Ampère's law (ignoring displacement currents) relates the magnetic field to the current I via

$$\oint \mathbf{B}\cdot d\boldsymbol{\ell} = \mu_0 I = \mu_0 c = Z_0 \tag{26}$$

This identity reveals a fundamental insight within our framework: the vacuum impedance $Z_0 = \mu_0 c$ is not merely an electromagnetic constant, but a quantized circulation of the magnetic field in response to the current $I = c$. Under the quasi-static regime, Ampère's law reduces to a direct proportionality between the magnetic field circulation and this structural current, leading to the elegant equivalence $\oint \vec{B}\cdot d\boldsymbol{\ell} = Z_0$.

In this light, Z_0 characterizes the vacuum's intrinsic resistance to topological twisting—a kind of "circulatory stiffness"—analogous to how μ_0 represents linear stiffness to deformation. When interpreted through the lens of dimensional collapse, where both μ_0 and I are dimensionless, this equation becomes a quantization condition: the magnetic excitation mode $\vec{B}$ must integrate to a unit value. This supports the interpretation of $\vec{B}$ as a topological mode of the unified field, constrained by geometric and symmetry conditions of the vacuum itself. In this sense, magnetism becomes a circulatory polarization of spacetime, fixed by the internal geometry and encoded in the impedance of the vacuum medium.

Integration with the Unified Modal Structure.

Within the unified field framework developed in Part IV (IX C), all static field modes—electric, magnetic, gravitational, and entropic—reduce to a common structural expression of the form:

$$\vec{\Phi}_X(r) = \frac{\mu_0}{4\pi r}\cdot C_X\cdot \hat{e}_X, \tag{27}$$

where $\mu_0/4\pi$ represents the universal elastic coupling of the vacuum, and C_X encodes the dimensionless constants specific to each mode (e.g., 2α, c, $\alpha^2 hc$, etc.). This structural form highlights the role of $\mu_0/4\pi$ as the elastic modulus that underlies all geometric field deformations, establishing a unifying framework across all physical interactions. In this context, the quasi-static form of Ampère's law,

$$\oint \vec{B}\cdot d\boldsymbol{\ell} = \mu_0 I = \mu_0 c = Z_0, \tag{28}$$

naturally integrates into this modal scheme. Interpreting $I = c$ as the structural current associated with a traveling quantum oscillator, the circulation integral of the magnetic field becomes:

$$\oint \vec{B}\cdot d\boldsymbol{\ell} \sim \int_0^{2\pi} \frac{\mu_0 c}{4\pi r}\cdot r\, d\theta = \mu_0 c = Z_0.$$

Thus, the vacuum impedance Z_0 is interpreted as a topological quantization constant associated with the magnetic mode—a circulatory stiffness analogous to the linear stiffness μ_0 of radial modes. In this context, magnetism is not merely a classical phenomenon, but a geometric polarization of the vacuum itself, arising from torsional deformation constrained by topological symmetry.

Topological Quantization and Modal Flux.

This reinterpretation of $Z_0 = \mu_0 c$ as a quantized circulation constant aligns with well-established principles of flux quantization in field theory. In quantum systems such as superconductors, magnetic flux is quantized in units of $\Phi_0 = h/2e$, while in classical electromagnetism, integral forms of Maxwell's equations impose global constraints on field flux. The unified modal formulation extends these principles by embedding them into the geometry of spacetime: the field circulation $\oint \vec{B}\cdot d\boldsymbol{\ell}$ must yield a fixed value determined by the internal structure of the vacuum. Hence, the elastic tensor framework not only recovers the standard laws, but elevates them to quantization conditions on the permissible excitations of the vacuum's geometry. This reinforces the central insight of Part IV: that all physical interactions arise as topologically constrained modal deformations of a single Lorentz-invariant field tensor $\mathcal{G}_{\mu\nu}$.

C. Vacuum Electromotive Responses: μ_0, K_e, and k_B as Modal Resonances from Faraday Dynamics

We can reinterpret the vacuum permeability μ_0, Coulomb's constant K_e, and Boltzmann's constant k_B as *effective electromotive responses*—emergent quantities characterizing the vacuum's elastic reaction to variations in structural currents over characteristic scales. This unifying view arises from Faraday's law, which describes the electromotive force induced by a time-varying magnetic flux:

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = -L_{\text{ind}} \cdot \frac{dI}{dt}. \tag{29}$$

In the framework of the unified tensor field $\mathcal{G}_{\mu\nu}$ (X), the current I represents a geometric deformation rate of the vacuum. Time and length are unified under the structural identification $[L] = [T]$, and current acquires the role of a velocity-like quantity: $I = L/T$. This dimensional symmetry allows us to reinterpret μ_0, K_e, and k_B as different modal resonances of the same underlying mechanism, depending on the deformation scale.

1. Reference Regime — Gravitational mode.

Let $I = 1\,\text{m/s}$ and $t = 1\,\text{s} \equiv 1\,\text{m}$. Using the base inductance $L_{\text{ind}} = \mu_0 \cdot 1\,\text{m}$, we find:

$$\mathcal{E} = \mu_0 \cdot 1\ \text{m} \cdot \frac{1}{1\ \text{s}} = \mu_0 \tag{30}$$

Thus, μ_0 characterizes the vacuum's minimal electromotive response to a unit deformation flow: the baseline voltage of the elastic field under quasi-static excitation.

2. Electromagnetic mode (scaled by c).

Scaling the current as $I = c$ implies $t = \frac{1\ s}{c}$, and using the same L_{ind}:

$$\mathcal{E} = \mu_0 \cdot 1\ \text{m} \cdot \frac{c}{\frac{1\ s}{c}} = \mu_0 c^2 = 4\pi K_e \tag{31}$$

We recover Coulomb's constant K_e as a relativistically scaled version of μ_0, confirming its nature as a voltage response under rapid deformation propagation.

3. Thermo-entropic mode (scaled by $1/c$).

Scaling the current as $I = 1/c$ yields $t = 1\ s \cdot c$. Then:

$$\mathcal{E} = \mu_0 \cdot 1\ \text{m} \cdot \frac{\frac{1}{c}}{1\ s \cdot c} = \frac{\mu_0}{c^2} \approx 1.4 \times 10^{-23} \tag{32}$$

which coincides numerically with Boltzmann's constant k_B, up to unit conventions. This identifies k_B as the thermo-entropic counterpart to μ_0 and K_e: an emergent voltage under slow deformation flux, consistent with the azimuthal thermal mode $\vec{T}$ derived from the unified tensor field (88).

These results confirm that μ_0, K_e, and k_B are not independent constants, but rather *modal projections* of the same elastic tensor structure. Each emerges from Faraday-like dynamics under a distinct current/time scaling regime:

- **Gravitational**: base mode, with $\mathcal{E} = \mu_0$,
- **Electromagnetic**: relativistic excitation, with $\mathcal{E} = \mu_0 c^2 = 4\pi K_e$,
- **Entropic**: dissipative/thermal excitation, with $\mathcal{E} = \mu_0/c^2 \approx k_B$.

In this view, all three constants describe the same underlying stiffness of the vacuum, observed at different frequencies of excitation. This directly supports the modal structure of Part IV, where each field expression $\vec{\Phi}_X(r) = \frac{\mu_0}{4\pi r} \cdot C_X \cdot \hat{e}_X$ arises from a specific symmetry and energy scale of the elastic vacuum.

As a result, Faraday's law, when interpreted in modal terms, provides a unified operational principle: *electromotive response emerges from geometric resistance to deformation.* The constants μ_0, K_e, k_B are expressions of the same elastic modulus μ_0, rescaled by the velocity I of excitation. This unifies electromagnetic, gravitational, and thermo-entropic interactions as frequency-dependent modes of a single deformable spacetime substrate.

D. The fine-structure constant α as half a damping ratio ζ and a Lorentz-like factor

The fine-structure constant α [20] can be defined as the ratio of two energies:

- the energy needed to overcome the electrostatic repulsion between two electrons a distance of d apart
- the energy of a single photon of wavelength $\lambda = 2\pi d$ (or of angular wavelength d)

Therefore, we have that

$$\alpha = \left(\frac{e^2}{4\pi\varepsilon_0 d}\right) \Big/ \left(\frac{hc}{\lambda}\right) = \frac{e^2}{4\pi\varepsilon_0 d} \times \frac{2\pi d}{hc} = \frac{e^2}{4\pi\varepsilon_0 d} \times \frac{d}{\hbar c} = \frac{e^2}{4\pi\varepsilon_0 \hbar c} \quad (33)$$

Other hand, in the context of an RLC circuit, the quality factor or Q factor [21] is a dimensionless parameter that describes how underdamped an oscillator or resonator is. It is defined as the ratio of the initial energy stored in the resonator to the energy lost in one radian of the cycle of oscillation. Therefore, we have that

$$Q \stackrel{\text{def}}{=} 2\pi \times \frac{\text{Energy stored}}{\text{Energy dissipated per cycle}} = 2\pi f_r \times \frac{\text{Energy stored}}{\text{Power loss}} = \omega_0 \times \frac{\text{Energy stored}}{\text{Power loss}} \quad (34)$$

Where f_r is the resonance frequency.

In electrical-engineering and condensed matter contexts, the fine-structure constant can be written as

$$\alpha = \frac{1}{4} Z_0 G_0,$$

where $Z_0 = \mu_0 c = \frac{1}{\varepsilon_0 c}$ is the vacuum impedance and $G_0 = \frac{2e^2}{h}$ is quantum conductance [22]. It follows that

$$Z_0 G_0 = 4\alpha,$$

which can be interpreted as the intrinsic energy loss characteristic per radian for the vacuum medium itself. Thus, one can naturally define a vacuum quality factor as

$$Q = \frac{1}{Z_0 G_0} = 2\pi \times \frac{\varepsilon_0 \hbar c}{2e^2} = \frac{1}{4\alpha}.$$

where we can identify $E_{\text{stored}} = \frac{\hbar c}{2\lambda}$ and $E_{\text{dissipated}} = \frac{e^2}{\varepsilon_0 \lambda}$.

The appearance of these two energies follows directly from well-established properties of a single electromagnetic vacuum mode of wavelength λ and the framework we have discussed throughout this Paper. On the one hand, quantum electrodynamics [23] dictates that each mode carries a zero-point energy

$$E_{\text{stored}} = \tfrac{1}{2}\hbar\omega = \tfrac{1}{2}\hbar\,(c/\lambda) = \frac{\hbar c}{2\lambda},$$

which is the exact reactive energy "stored" in the vacuum field for an angular frequency $\omega = \frac{c}{\lambda}$.

On the other hand, using Hooke's Law, we can identify the dissipated energy using the formula $E = -kx^2$ where k is the elasticity constant, and x the displacement [24]. As in the context of the unified field we have identified $k = \frac{1}{C} = \frac{1}{\varepsilon_0 \lambda}$, and the displacement x with the electric charge Q, we get that $E_{\text{dissipated}} = -kx^2 = \frac{e^2}{\varepsilon_0 \lambda}$.

Alternatively, as a sanity check that the above is consistent with well-established derivations, consider an oscillating dipole $p(t) = p_0 \cdot cos(\omega t)$ with amplitude $p_0 = e \cdot d$, where $d = \lambda/(2\pi)$ is the separation and $\omega = c/d$ is the angular frequency. Using Larmor formula for time-averaged power radiated by an oscillating dipole [16]:

$$\langle P \rangle = \frac{p_0^2 \omega^4}{12\pi\varepsilon_0 c^3} \quad (35)$$

we can derive the energy dissipated per cycle (period $T = 2\pi/\omega$):

$$E_{\text{dissipated}} = \langle P \rangle \times T = \left(\frac{p_0^2 \omega^4}{12\pi\varepsilon_0 c^3}\right)\left(\frac{2\pi}{\omega}\right) \quad (36)$$

And substituting and operating, one finally gets that

$$E_{\text{dissipated}} = \frac{\pi e^2}{3\varepsilon_0 \lambda} \approx 1.05 \cdot \frac{e^2}{\varepsilon_0 \lambda} \quad (37)$$

Thus, both energies can be derived from first-principles and lead directly to

$$Q = 2\pi \times \frac{E_{\text{stored}}}{E_{\text{dissipated}}} = 2\pi \times \frac{\hbar c/(2\lambda)}{e^2/(\varepsilon_0\, \lambda)} = \frac{1}{4\alpha},$$

For an underdamped oscillator, the damping ratio is defined as

$$\zeta = \frac{1}{2Q},$$

which leads directly to

$$\boxed{\zeta = 2\alpha}$$

Interpreting c in terms of the Damped Resonant Frequency of the System

In a standard underdamped oscillator model [25–27], the damped frequency ω_d is given by

$$\omega_d \;=\; \omega_0 \sqrt{1 - \zeta^2}, \quad (38)$$

where ω_0 is the *undamped* resonant (natural) frequency of the system, and ζ is the damping ratio.

Suppose we associate these frequencies with propagation speeds by multiplying each angular frequency by a reference length of *one meter*, yielding speeds in units of $\mathrm{m\,s^{-1}}$. Denoting:

$$v_{\text{damped}} \;=\; \omega_d \times 1\ \mathrm{m}, \quad v_{\text{undamped}} \;=\; \omega_0 \times 1\ \mathrm{m},$$

we can identify v_{damped} with the *measured* speed of light, conventionally denoted by c. In other words,

$$c \;=\; v_{\text{damped}} \;=\; \omega_d \times 1\ \mathrm{m}.$$

From Eq. (38), we thus have

$$c \;=\; \omega_0 \cdot 1\ m\sqrt{1-\zeta^2}$$

Or, equivalently,

$$c^2_{\text{measured}} = c^2_{\text{real}}(1-(2\alpha)^2) \tag{39}$$

Which, solving for ζ, can be rewritten as

$$\zeta = 2\alpha = \sqrt{1-\frac{c^2_{\text{measured}}}{c^2_{\text{real}}}} \tag{40}$$

Note the similarity of the above expression with the reciprocal of the Lorentz factor formula [28]. Thus, the fine-structure constant α can be regarded as the reciprocal of a "Lorentz-like" factor via

$$\zeta = 2\alpha \;=\; \frac{1}{\gamma} \;=\; \sqrt{1-\frac{c^2_{\text{measured}}}{c^2_{\text{real}}}}\,. \tag{41}$$

These two views—the *damped oscillator* analogy for electromagnetic propagation and the *Lorentz-like* factor interpretation for α—are not only compatible, but in fact reinforce each other: α emerges as a geometric or relativistic "scaling factor" that governs attenuation in the oscillatory unified field, connecting electromagnetic propagation and the quantum vacuum's dissipative properties.

Vacuum Damping and potential relationship to Earth's Motion

Note that, solving for c_{real}, one gets

$$c_{\text{real}} = \frac{c}{\sqrt{1-4\alpha^2}} \approx 299.824.388\ \mathrm{m\ /\ s} \tag{42}$$

This implies an intrinsic scale difference $\Delta c \;=\; c_{\text{real}} - c_{\text{measured}} \;=\; 31,927\ \mathrm{m/s}$. Note that this velocity is numerically very close to the Earth's translational velocity.

Throughout this Paper, we are proposing that the quantum vacuum itself acts as a structured, elastic–dissipative medium. And, just as wave propagation in a structured medium may exhibit Doppler-type modulations, a moving observer within the dissipative vacuum may experience direction-dependent attenuation—without implying a classical ether or absolute frame.

One might then ask whether the full damping effect Δc could arise solely from Earth's motion through a static vacuum rest frame. While motion through a medium can indeed lead to velocity-dependent modifications of wave propagation—such as in Fresnel drag [29] or Cherenkov radiation [30]— if Δc depended entirely on Earth's motion, we would expect measurable deviations in the speed of light between different inertial frames, in conflict with local Lorentz invariance. Instead, we interpret Δc as arising from the vacuum's intrinsic elastic and dissipative response, while motion relative to the vacuum introduces only small, direction-dependent modulations $\delta c(v)$ atop this universal baseline. This layered structure preserves relativistic consistency while offering a physically grounded mechanism for both the constant and modulated components of the observed light speed.

In this picture, the vacuum consists of fluctuating virtual excitations with internal degrees of freedom that collectively endow it with both stiffness (reactive elasticity) and finite relaxation time (viscosity). A propagating electromagnetic wave then loses energy—not into real particles, but into the hidden structure of the vacuum—via coupling to these degrees of freedom. This loss manifests macroscopically as a damping ratio ζ, which we identify with the dimensionless fine-structure constant via $\zeta = 2\alpha$. Such a damping constant is natural if one treats the vacuum as an ensemble of coupled oscillators or as an emergent condensed-matter system, as suggested by various approaches to quantum gravity and emergent spacetime [31–33]. The resulting reduction in propagation speed is then not a kinematic effect, but a first-principles consequence of quantum back-reaction. This allows us to interpret the measured speed of light c as a damped, effective velocity arising from the underlying dissipative structure of the vacuum.

Thus, the near-coincidence between the damping shift $\Delta c = c_{\text{real}} - c$ and the Earth's translational velocity suggests a deeper possibility: that this difference encodes a global topological feature of the vacuum field. In our framework, the quantum vacuum is not an inert background but a structured elastic-dissipative medium with internal degrees of freedom. The quantity Δc may then reflect a background excitation of this medium —

a large-scale deformation mode aligned with the Earth's translational trajectory.

Importantly, this view does not violate local Lorentz invariance. All local observers measure the same effective speed $c = c_{\text{measured}}$, and all physical laws remain Lorentz-invariant in that frame. The distinction between c_{real} and c thus becomes a global, geometric feature of the vacuum — akin to how curvature encodes gravitational effects in general relativity. In this case, however, the "curvature" is not geometric but modal: a manifestation of the vacuum's internal damping modes, whose excitation state defines a preferred frame only at a topological level, not at the level of measurable kinematics.

Final notes

It is worth noting that although we have identified a "bare" or "undamped" speed of light, c_{real}, as exceeding the measured value c, *this does not conflict with the established principle that the speed of light is the maximum signal velocity.* In our picture, all physical processes remain measured by the *effective*, damped value of c; hence, no measurable signal can exceed c. Analogous to an RLC circuit, where the "natural" frequency ω_0 is never directly observed but rather only inferred through modeling, the proposed $c_{\text{real}} > c$ does not admit superluminal information transfer, and thus poses no contradiction to special relativity or experiment.

Other hand, higher–order radiative effects — e.g. the electron's anomalous magnetic moment $a_e = \alpha/2\pi$ — can be viewed as additional layers of the same dissipative mechanism. The damping encoded in the fine-structure constant α would be the first-order manifestation of how the vacuum's oscillator lattice "bleeds" energy back into itself through quantum fluctuations, and the anomalous magnetic moment can be viewed, in our framework, as the simplest radiative attenuation of a bare "undamped" coupling by the lattice's elastic resistance. Higher-order Feynman diagrams then correspond to more intricate couplings among modes of the vacuum, each contributing successive powers of α.

More generally, any "ideal" relation among fundamental constants—whether in electromagnetism, gravitation or thermodynamics—must be dressed by a universal, dimensionless form factor $\Xi_{\text{eff}}(\alpha)$ that encodes the accumulated effect of loop-induced damping within the vacuum lattice. In this way, radiative corrections are not mere perturbative afterthoughts, but the fingerprint of the same elastic and dissipative structure that unifies all fields at their quantum origin.

In this view, the fine-structure constant α becomes not merely a coupling constant, but a unifying signature of modal attenuation across all field interactions — electromagnetic, gravitational, and thermo-entropic alike.

E. From the equipartition theorem to the harmonic oscillator energy and the fundamental equation

The equipartition theorem [19] shows that in thermal equilibrium, some harmonic oscillator has an average energy of:

$$\langle E \rangle = k_B T. \tag{43}$$

Other hand, for each quantum harmonic oscillator, the fundamental action per complete cycle is given by Planck's constant h; therefore, the average total energy required to excite some quantum harmonic oscillator to the next quantum level is:

$$\langle E \rangle = h\omega \tag{44}$$

Equating both expressions, and incorporating relativistic corrections -with a Lorentz factor γ-, we have that:

$$k_B T = h\omega \cdot \gamma$$

Substituting by $\gamma = \frac{1}{2\alpha}$ and $\omega = \frac{c}{\lambda}$, we get the fundamental equation

$$k_B T = \frac{h \cdot c}{\lambda \cdot 2\alpha} \tag{45}$$

If we set $T = 1K \equiv 1\ m$ and $\lambda = 1\ m$, we get that

$$k_B \cdot 2\alpha = \frac{h \cdot c}{1\ m^2} \approx 2 \times 10^{-25}$$

Moreover, if we consider the minimum structural voltage μ_0 (30) and the elementary charge e, one can posit the fundamental equation

$$\boxed{\mu_0 \cdot e = k_B \cdot 1\ K \cdot 2\alpha = \frac{hc}{1\ m}} \tag{46}$$

The above makes sense both numerically and theoretically. Numerically, note that

$$\frac{k_B \cdot 2\alpha}{\mu_0} = 1.38 \times 10^{-23} \cdot 2 \cdot 0.007297 \cdot 4\pi \times 10^{-7} \approx 1.602 \times 10^{-19} \tag{47}$$

Recall that, theoretically, it comes naturally to construct the quantum of charge e_q as the product of the structural voltage μ_0 and the structural capacitance $\varepsilon_0 \cdot 1\ m$, to get that $e_q = \frac{1\ m}{c^2}$ (23). Note that then we have that $\mu_0 \cdot e_q = \frac{\mu_0 \cdot 1\ m}{c^2} = k_B \cdot 1\ K$. Accounting for relativistic corrections using $\gamma = \frac{1}{2\alpha}$, one has (46), and also that

$$e = \frac{1\ m}{c^2 \cdot \gamma} = \frac{2\alpha \cdot 1\ m}{c^2} \tag{48}$$

This relations provide a profound synthesis between thermal, quantum, electromagnetic, and geometric domains. The fundamental equation encapsulates, in a single concise expression, this Paper's overarching claim that multiple "fundamental constants" can be viewed as interrelated manifestations of an underlying quantum-oscillatory vacuum.

F. The gravitational constant G as some structural electromotive force $\mathcal{E}$ of the unified field

As by definition $K_e = \frac{\mu_0 \cdot c^2}{4\pi}$, one has that

$$K_e \cdot 4\pi \cdot e = \frac{e}{\varepsilon_0} = \Phi_E = \oint_S \vec{E} \cdot d\vec{A}$$

As we have established that $e = \frac{2\alpha \cdot 1\ m}{c^2}$, we can substitute to obtain that

$$\begin{aligned} \Phi_E &= \frac{\mu_0 \cdot c^2}{4\pi} \cdot 4\pi \cdot \frac{2\alpha \cdot 1\ m}{c^2} \\ &= \mu_0 \cdot 2\alpha \cdot 1\ m = \frac{\mu_0 \cdot 1\ m}{\gamma} \end{aligned} \tag{49}$$

We recall that the electric flux is defined as

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A},$$

while the electromotive force (emf) is given by

$$\mathcal{E}_{\text{elec}} = \oint_{\partial S} \vec{E} \cdot d\vec{\ell}.$$

In the case of a spherically symmetric or radially uniform field over a region of characteristic radius $r = 1$ m, we can establish the effective structural electromotive force as:

$$\mathcal{E}_{\text{elec}} = \frac{\Phi_E}{1\ \text{m}} = \mu_0 \cdot 2\alpha$$

Now, the symmetry between gravitational and electromagnetic interactions in our framework imposes the equivalence

$$[G] = [K_e],$$

As it makes sense both numerically and theoretically, we postulate that

$$\begin{aligned} &G \cdot \gamma = \frac{1}{4}\mathcal{E}_{elec} \rightarrow \\ &G = \frac{1}{4}\mu_0 \cdot 2\alpha \cdot 2\alpha = \mu_0 \cdot \alpha^2 \end{aligned} \tag{50}$$

Numerically, we have that

$$G = \mu_0 \alpha^2 \approx 6.69 \times 10^{-11} \tag{51}$$

showing that the gravitational constant naturally arises as an effective structural electromotive response, quadratically scaled by the fine-structure damping ratio $\zeta = 2\alpha$.

The structural damping tensor $\zeta_{\mu\nu}$ and the emergence of gravitational stiffness

Theoretically, note that the gravitational constant G takes the form:

$$G = \mu_0 \cdot \frac{1}{4}\zeta^2 \tag{52}$$

where $\zeta = 2\alpha$. Note how this mirrors the structure of the electromagnetic Lagrangian,

$$\mathcal{L}_{EM} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu},$$

suggesting the idea that gravity itself is a quadratic manifestation of the unified field's intrinsic resistance to deformation or energy storage. In this picture, G represents the gravitational "stiffness" of the field—the extent to which the vacuum resists coherent longitudinal deformation due to massive excitations, just as the magnetic permeability μ_0 governs transverse oscillations under charge.

This naturally motivates a tensorial generalization, where we promote $\zeta = 2\alpha$ to the norm of a rank-2 symmetric tensor $\zeta_{\mu\nu}$, which we define as the *structural damping tensor* of the vacuum. This tensor encodes the internal dissipation response of the quantum vacuum to perturbations in spacetime, such that its contraction yields the effective damping strength:

$$\zeta^2 = \zeta_{\mu\nu}\zeta^{\mu\nu} \tag{53}$$

In this formulation, gravitational coupling is no longer introduced as an independent constant but instead emerges from the structural dissipation of the vacuum. This structural damping tensor $\zeta_{\mu\nu}$ acts as the unifying link between electromagnetic, gravitational, and thermo-entropic responses of the vacuum medium, and provides a natural geometric origin for Newton's constant.

Relationship between the structural damping tensor $\zeta_{\mu\nu}$ and the fundamental symmetric tensor $\mathcal{G}_{\mu\nu}$

As introduced in Part IV (X), the symmetric tensor $\mathcal{G}_{\mu\nu}$ encodes the fundamental strain modes of the unified vacuum field, from which all classical fields derive as projections. We can relate it to the structural damping tensor $\zeta_{\mu\nu}$, responsible for gravitational coupling, by invoking the classical analogy with stress–strain relations in continuum mechanics [34, 35], where the potential energy is given by $E_{\text{pot}} = \frac{1}{2}\sigma_{\mu\nu}\epsilon^{\mu\nu}$, with $\sigma_{\mu\nu}$ the stress tensor and $\epsilon^{\mu\nu}$ the strain tensor. In our framework, the fundamental symmetric tensor $\mathcal{G}_{\mu\nu}$ plays the role of the strain, while the structural damping tensor $\zeta_{\mu\nu}$ naturally corresponds to the induced internal stress. We thus interpret gravity as the manifestation of a quadratic response of the vacuum field:

$$\zeta_{\mu\nu} \propto \mathcal{G}_{\mu\alpha}\mathcal{G}^{\alpha}{}_{\nu},$$

so that the gravitational constant G encodes the vacuum's effective elastic stiffness to coherent deformation. This identification completes the mechanical analogy and anchors Newton's constant within the internal modal dynamics of the unified field.

Interpretation of $G = \mu_0 \cdot \frac{1}{4}\zeta^2$ as a Constitutive Law of the Vacuum

As a result, $G = \mu_0 \cdot \frac{1}{4}\zeta^2$ admits a natural interpretation within our unified field framework: it is the constitutive law that relates the vacuum's transverse rigidity μ_0 to its longitudinal stiffness G through the internal damping response $\zeta^2 = \zeta_{\mu\nu}\zeta^{\mu\nu}$. In direct analogy with classical elasticity theory, where the stored elastic energy takes the form $E_{\text{pot}} = \frac{1}{2}\sigma_{\mu\nu}\epsilon^{\mu\nu}$, we may view $\zeta_{\mu\nu}$ as the internal stress tensor of the vacuum, induced by the strain field $\mathcal{G}_{\mu\nu}$. In this picture, gravity emerges as the quadratic response of the vacuum's elastic-dissipative lattice to coherent longitudinal deformations induced by mass-energy excitations.

Thus, the gravitational constant G is not fundamental, but derived: it encodes the effective elastic modulus of the vacuum along longitudinal modes, just as μ_0 encodes transverse response. The relation $G = \mu_0 \cdot \frac{1}{4}\zeta^2$ then completes the analogy with continuum mechanics, anchoring the gravitational interaction in the internal modal geometry and dissipative structure of the vacuum field.

1. The fine-structure constant as a quotient of gravitational constant and magnetic permeability

As a final note, the above allows us to relate the fine-structure constant α to the ratio of gravitational constant G and the vacuum permittivity μ_0:

$$\alpha = \sqrt{\frac{G}{\mu_0}} \tag{54}$$

This relation has several noteworthy implications:

- **Dimensional consistency and field symmetry:** Within our framework, both G and μ_0 share the same structural dimensionality, being expressed as effective field stiffnesses or "structural electromotive constants" of the vacuum. Their ratio is thus dimensionless, and α appears as a normalized measure of the coupling between longitudinal (gravitational) and transverse (electromagnetic) responses of the vacuum field.
- **Geometric attenuation coefficient:** From the structural damping interpretation, we have $\zeta = 2\alpha$, and since $G = \mu_0 \cdot \frac{1}{4}\zeta^2$, the identity $\alpha = \sqrt{G/\mu_0}$ simply inverts that structure. This confirms that α is not a fundamental constant per se, but the *geometric attenuation coefficient* resulting from the interplay between elastic (magnetic) and dissipative (gravitational) responses of the vacuum.
- **Coupling of fields through the vacuum lattice:** This formula can also be interpreted as stating that the strength of electromagnetic coupling (α) is not an independent input, but a direct consequence of how gravitational and magnetic degrees of freedom couple within the same medium. The fine-structure constant is thereby elevated from a fixed parameter to a derived measure of vacuum coupling topology.
- **Emergent gauge unification:** Finally, this identity hints at a deeper symmetry: one in which the gauge interactions of electromagnetism (through μ_0) and the geometric deformation field of gravity (through G) are dual aspects of the same resonant vacuum structure. In this light, the fine-structure constant emerges as the universal damping ratio that governs all interaction strengths, mediating how local excitations propagate through this unified background.

In conclusion, this corollary supports the overarching thesis of this work: that all physical constants—gravitational, electromagnetic, and quantum—are not separate inputs but instead arise from the intrinsic structure, resonant modes, and dissipation characteristics of the quantum-elastic vacuum field.

G. Derivation of the Gravitational Constant G in terms of ε_0

As a complementary derivation to the dynamical framework previously introduced—where G emerges from the structural electromotive response of the vacuum—we now turn to a static-field perspective based on classical electrostatics. This alternative approach leads to the same result, reinforcing the idea that gravity and electromagnetism are orthogonal projections of a common vacuum elasticity.

Consider the energy U required to assemble a sphere of charge with a uniform charge density, also known as the self-energy of some sphere [36], with elementary charge e and radius r, which can be expressed [36] as

$$U_{sphere} = \frac{3}{5} \cdot \frac{e^2}{4\pi\varepsilon_0 r} \tag{55}$$

The total energy U in the system is related to its capacitance C and the potential V by:

$$U = CV^2$$

The potential (voltage) V at the surface of the sphere [15] is:

$$V = \frac{1}{4\pi\varepsilon_0}\frac{e}{r}$$

We can express C in terms of the self-energy U and the potential V as:

$$C = \frac{U}{V^2}$$

Substituting the expressions for U and V, and operating, we have:

$$C = \frac{U}{V^2} = \frac{\frac{3}{5} \cdot \frac{e^2}{4\pi\varepsilon_0 r}}{\left(\frac{1}{4\pi\varepsilon_0}\frac{e}{r}\right)^2}$$
$$= \frac{3}{5}4\pi\varepsilon_0 r \rightarrow \frac{C}{r} = \frac{3}{5}4\pi\varepsilon_0 \tag{56}$$

Within our framework, $[C] = [L] = [T]$ and ε_0 becomes dimensionless, so both sides of the equation become dimensionless (and thus, dimensionally consistent).

Note that, numerically, with the current accepted value for ε_0 [37], we have that

$$\frac{3}{5} \cdot 4\pi\varepsilon_0 \approx 6.6759 \times 10^{-11}$$

Which is indeed pretty close to the established value of the gravitational constant G [38].

Structural Interpretation of $G \propto \varepsilon_0$: Reciprocity between gravitational stiffness and electromagnetic tension

The previous derivation of the gravitational constant G from the electrostatic self-energy of a charged sphere arises naturally from the structural link between the gravitational coupling and the electric permittivity of the vacuum, once we have established that mass M and charge Q are structurally equivalent quantities within the unified oscillator model, i.e., $[M] \equiv [Q]$.

Note the precise structural similarity between the gravitational and electric field equations:

Field Law	**Electrostatics**	**Gravitation**
Gauss' law (diff.)	$\nabla\vec{E} = \frac{\rho_e}{\varepsilon_0}$	$\nabla\vec{g} = -4\pi G\rho_m$
Radial field	$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$	$g = G\frac{M}{r^2}$
Potential field	$\phi_E = \frac{Q}{4\pi\varepsilon_0 r}$	$\phi_G = -\frac{GM}{r}$
Self-energy (sph.)	$U_E = \frac{3}{5}\frac{Q^2}{4\pi\varepsilon_0 r}$	$U_G = -\frac{3}{5}\frac{GM^2}{r}$

These expressions differ only in sign (attractive vs. repulsive) and in their coupling constants: ε_0^{-1} and G, respectively. If mass and charge are interpreted as equivalent structural sources of field deformation, then the vacuum constants ε_0 and G must also be manifestations of the same underlying property of space: its stiffness in response to static source configurations.

Under this view, ε_0 measures the electric deformability of the vacuum (i.e., how easily it allows displacement fields due to charge), while G measures its gravitational deformability (how easily it allows curvature or acceleration fields due to mass). The gravitational constant G and the permittivity ε_0 are not independent quantities, but different expressions of the same underlying elastic-dissipative geometry of the vacuum. The equivalence becomes inevitable when the laws governing the fields are functionally identical and the sources (mass and charge) are structurally interchangeable.

In this context, our postulate

$$G = \frac{3}{5}4\pi\varepsilon_0 = \frac{3}{5}\frac{1}{K_e}$$

proposes a natural reciprocity: the vacuum's *longitudinal compliance* (gravitational softness) is inversely proportional to its *transverse stiffness* (electromagnetic tension). Put differently, the vacuum's ability to resist gravitational deformation is weakest precisely because it is most rigid electromagnetically. The stronger the electric field that the vacuum can sustain, the weaker the gravitational interaction that can emerge from the same medium.

This duality highlights a profound symmetry: *gravity and electromagnetism are orthogonal projections of the same underlying field elasticity.* The vacuum's ability to deform under longitudinal (gravitational) excitation is far more limited than under transverse (electromagnetic) excitation. In other words, the vacuum is extremely stiff in response to mass-like perturbations (as encoded in the smallness of G), and relatively compliant to charge-like perturbations (as seen in the largeness of K_e).

This not only reinforces the modal equivalence described previously but gives it a new dimension: the vacuum acts as a geometric impedance surface, whose tension and compliance balance across regimes to define the apparent strengths of fundamental forces. The interpretation $G \propto \varepsilon_0 \sim 1/K_e$ thus follows naturally as a structural necessity within this framework.

In conclusion, the result $G \propto \varepsilon_0$ is not an isolated numerical coincidence but the most natural consequence of structural equivalence between mass and charge. It validates the idea that all coupling constants emerge from a single elastic-dissipative fabric of space, whose geometric and energetic responses define the laws of physics as we experience them.

H. Corollaries: re-expressing Newton's Law and Coulombs Law in terms of momentum transfer in different modes

From the previously derived equivalences, such as $G = \mu_0 \cdot \alpha^2$ and $k_B = \mu_0/c^2$, it follows that:

$$G = k_B \cdot \alpha^2 \cdot c^2$$

This allows us to re-express Newton's gravitational law as a thermo-entropic interaction:

$$\frac{F_g}{4} = k_B \cdot \frac{\left(\frac{Mc}{\gamma}\right) \cdot \left(\frac{mc}{\gamma}\right)}{r^2},$$

where $\gamma = \frac{1}{2\alpha}$.

The prefactor $\frac{1}{4}$ reflects the same quadratic damping structure appearing both in the electromagnetic Lagrangian $\mathcal{L}_{EM} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu}$ and our expression for the gravitational stiffness $G = \mu_0 \cdot \frac{1}{4}\zeta^2$. It encodes the modal character of the gravitational field as a second-order elastic response to projected momentum densities through the vacuum lattice, via the symmetric tensor $\zeta_{\mu\nu} \propto \mathcal{G}_{\mu\alpha}\mathcal{G}^{\alpha}{}_{\nu}$. Thus, the factors $\frac{Mc}{\gamma}$ and $\frac{mc}{\gamma}$ correspond to effective, damped relativistic momenta —not because particles move at light speed, but because their gravitational field propagates through the vacuum's elastic-dissipative structure. These momenta are longitudinal projections of the energy-momentum current I_g, whose propagation is modulated by the damping structure encoded in $\zeta_{\mu\nu}$. Thus, gravity emerges as the effective resistance to the coherent alignment of projected momenta through the vacuum's dissipative tensorial geometry.

By symmetry, the Coulomb force can be reformulated analogously as a transverse-mode momentum interaction:

$$F_e = K_e \cdot \frac{Q_1 Q_2}{r^2} = \frac{\mu_0 \cdot c^2}{4\pi} \cdot \frac{Q_1 Q_2}{r^2} = \mu_0 \cdot \frac{(Q_1 c)(Q_2 c)}{4\pi r^2}$$

This structure mirrors the gravitational expression, with Qc playing the role of transverse modal momentum and the vacuum magnetic permeability μ_0 acting as the transverse field stiffness. Thus, both Newton's and Coulomb's laws appear as complementary modal projections of the same unified vacuum tensorial response, mediated by $\mathcal{G}_{\mu\nu}$ and its derived damping structure $\zeta_{\mu\nu}$.

Momentum Transfer and Entropic Gradient Interpretation

In this formulation, both gravitational and electromagnetic interactions arise as manifestations of momentum exchange through a medium with intrinsic damping. For gravity, the damping factor $\gamma = 1/(2\alpha)$ emerges from the vacuum's resistance to longitudinal deformation, requiring greater energy or mass to transmit equivalent field influence. The Boltzmann constant k_B, here, quantifies the entropy cost per unit of squared momentum transfer, embedding gravitational force within a statistical mechanics framework.

This aligns with the heuristic view that gravity arises from the statistical organization of vacuum degrees of freedom. The product $p_M p_m \sim (Mc)(mc)$ defines a correlation between the relativistic momenta of two masses. Dividing by r^2 reflects the dilution of momentum correlation due to spatial dispersion in an entropic field, whose effective stiffness is modulated by $\zeta = 2\alpha$.

Electromagnetism, analogously, corresponds to a transverse mode where the vacuum responds to current-like excitations. Charges Q and q, moving at light speed, define maximal transverse stress contributions, and the vacuum responds with a resistance determined by μ_0. Thus, K_e, μ_0, and G all measure the vacuum's ability to redistribute momentum between sources — filtered by geometry, damping, and scale.

In summary, both interactions reflect momentum exchange across a structured medium. What differs is the symmetry (transverse vs. longitudinal), the effective damping, and the entropy associated with deformation. The gravitational force emerges as a highly suppressed, entropy-weighted momentum flow — not because the vacuum is weakly coupled, but because it is *rigid* against longitudinal oscillations, whereas the electromagnetic force reflects a more efficient, transversely mediated momentum exchange, amplified by the vacuum's comparatively soft resistance to shear-like charge deformations.

Relationship between the gravitational constant G and c

As a final -and crucial- note on the gravitational constant G, substituting $G = \mu_0 \cdot \alpha^2$ one can check that

$$G \cdot c = \mu_0 \cdot c \cdot \alpha^2 = Z_0 \cdot \alpha^2 \approx \frac{1}{50}$$

where $Z_0 = \mu_0 c \approx 377\,\Omega$ is the vacuum impedance. Numerically, this yields:

$$G \cdot c \approx \frac{1}{50}$$

This dimensionless combination suggests that the product $G \cdot c$ defines a fundamental 'resistive-like' constant of the vacuum, which we denote as the *natural resistance* X_N. Motivated both by numerical proximity and by its appearance in the Einstein-Hilbert action pre-factor, we propose that:

$$X_N := G \cdot c = \frac{1}{16\pi}$$

from which one can formally write:

$$c = \frac{1}{16\pi G} \tag{57}$$

This postulate is not arbitrary: the factor $\frac{1}{16\pi G}$ appears in the Einstein-Hilbert action

$$S = \frac{c^4}{16\pi G} \int R\sqrt{-g}\, \mathrm{d}^4x,$$

suggesting that G and c are not entirely independent constants, but rather encode dual aspects of the vacuum's elastic and dissipative structure. In our framework, where both μ_0 and α characterize the internal stiffness and attenuation of the vacuum, the combination $G \cdot c \sim Z_0 \cdot \alpha^2$ reflects the effective coupling between the responses of the gravitational and electromagnetic field.

We will exploit this equivalence later to derive an expression of the gravitational Lagrangian and to connect the Einstein-Hilbert action with thermodynamic and modal principles in the unified field (IX B 1).

I. Derivation of the Casimir Constant C_c

The magnitude of the Casimir force per unit area A between two perfectly conducting plates separated by a distance d is classically given by:

$$\frac{F_C}{A} = -\frac{\pi^2 \hbar c}{240 d^4} \approx \frac{1.3 \times 10^{-27}\ N \cdot m^{-2}}{d^4},$$

where $\hbar$ is the reduced Planck constant and c is the speed of light in a vacuum. The calculation of this expression involves handling a divergent sum using a regularization technique involving the Riemann zeta function. Using our model, we can avoid the divergence handling and directly relate the Casimir effect to vacuum energy density.

Let us define the Casimir constant C_c as the quantum of "Casimir effect" force por unit of area. The zero-point energy per quantum oscillator, $E_0 = \frac{\hbar c}{2\cdot\lambda}$, produces an elementary electromotive-like force $\mathcal{E}_0 = \frac{\hbar c}{2\cdot\lambda^2}$, which, divided by the surface area of a sphere $4\pi r^2$ and choosing the characteristic length scale $\lambda = r = 1$ m, we obtain the Casimir constant::

$$C_c = \frac{F_{qho}}{A} = \frac{\frac{\hbar c}{2}}{4\pi \cdot 1\ m^4} \approx 1.26 \times 10^{-27}\ N \cdot m^{-2}$$

This value agrees with both theoretical estimates and experimental measurements [39, 40], and illustrates the vacuum's intrinsic capacity to sustain baseline oscillatory stress, constrained by spacetime geometry. Thus, we may write:

$$\frac{F_C}{A} = \frac{C_c}{d^4} = \frac{\frac{\hbar c}{2}}{4\pi \cdot (1\ \mathrm{m})^4 \cdot d^4}, \tag{58}$$

which offers a more direct and physically intuitive way to compute the Casimir force, bypassing the need for divergent series summation or zeta-function regularization.

J. The elementary charge as the quotient of mass at rest and total relativistic energy

Recall the equation

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A} = \mu_0 \cdot 1\ m \cdot 2\alpha = \frac{e}{\varepsilon_0}$$

Note that, solving for the elementary charge e, and as $\varepsilon_0\mu_0 = \frac{1}{c^2}$, we get our already derived expression

$$e = \mu_0\varepsilon_0 \cdot 1\ m \cdot 2\alpha = \frac{2\alpha \cdot 1\ m}{c^2}$$

As we have established that μ_0 has dimension of voltage V, and that $\varepsilon_0 \cdot 1\ m$ is a capacitance C, then we have that

$$[e] = \left[\frac{C \cdot V}{\gamma}\right]$$

Which is dimensionally consistent, and provides a new interpretation of the elementary charge as a product of the vacuum's electromagnetic properties, encapsulated by its capacitance ε_0 and voltage μ_0, and modulated by α as some Lorentz factor γ. This formulation aligns with the notion that the elementary charge is an emergent property of the vacuum, induced by its interaction with relativistic effects.

Moreover, note that for any mass at rest m_0 we have

$$e = \frac{m_0}{m_0 \cdot c^2 \cdot \gamma} \tag{59}$$

As a result, e can be interpreted as the quotient of some mass at rest, and the total relativistic energy of that mass. This connects charge directly to relativistic energy–momentum structure, framing it as a *transverse projection* of mass–energy coupling, in contrast to gravity's longitudinal projection.

The above points toward a deeper unity between electromagnetism and geometry. In this framework, electric charge can be reinterpreted as a gauge–geometric defect—a localized deformation arising from how mass–energy interacts with the vacuum's transverse modes. While mass induces longitudinal curvature associated with gravitation, charge emerges as the transverse projection of this same mass–energy content, modulated by the vacuum's elastic and dissipative structure. In particular, the elementary charge e reflects the vacuum's ability to support shear-like deformations sourced by relativistic–non-relativistic coupling. Rather than a primitive electromagnetic label, it becomes a geometric signature of transverse curvature in the spacetime lattice—an imprint of how mass–energy interacts with internal vacuum symmetries through the damping tensor $\zeta_{\mu\nu}$. This reinforces the central idea that charge, mass, energy, and spacetime curvature are not independent attributes, but modal expressions of a single elastic-dissipative field. Their apparent distinctions arise from how energy–momentum flows project onto different tensorial modes—longitudinal or transverse—within the unified geometric fabric of the vacuum.

Final remark:

The formula links the elementary charge to the motion of the particles that are "suitable" to have charge. This suggests that the elementary charge is not simply a static property but one that depends on the fundamental particle's interaction with spacetime itself, particularly through its relativistic spin and magnetic dipole moment, both of which are transverse in nature. In this light, the elementary charge appears as a *topological quantization* of transverse curvature modes around localized energy densities. Charge could arise from internal rotational or topological properties, becoming a geometrical descriptor of vacuum deformation in the presence of matter and motion.

Part III: the basis of the fundamental entropic field

V. MASS AS AN EMERGENT PROPERTY OF SPACETIME ELASTICITY

In this section, we formalize the reinterpretation of mass as an emergent property of spacetime. By considering Hooke's law and Newton's law as the most fundamental force laws, we derive a new perspective on mass linked to the elasticity of spacetime.

A. Derivation of mass from Hooke's Law and Newton's Law

Hooke's law states that the force exerted by an elastic system is proportional to the displacement:

$$\vec{F} = -k\vec{x}, \tag{60}$$

where k is the elasticity constant and $\vec{x}$ is the displacement from the equilibrium position. On the other hand, Newton's second law expresses force as:

$$\vec{F} = m \cdot \vec{a}, \tag{61}$$

where $\vec{a}$ is the acceleration. Equating both expressions:

$$m \cdot a = -k \cdot x. \tag{62}$$

Since acceleration can be rewritten as $\vec{a} = d^2x/dt^2$, solving for m, we obtain:

$$m = -k \cdot \frac{x}{a} \rightarrow [m] = -[k][T^2]. \tag{63}$$

B. Action as the Fundamental Elastic Response of Spacetime

We now interpret the term x/a within the context of spacetime elasticity. Since action S is defined as the integral of the Lagrangian over time:

$$S = \int L\,dt, \tag{64}$$

and given that the Lagrangian L is the difference between kinetic and potential energy,

$$L = T - V, \tag{65}$$

we observe that displacement x modifies the relationship between kinetic and potential energy, while acceleration a governs the rate of change in this transformation. Noting that, applying the equivalence $M \equiv L \equiv T$, action has the same dimensional form as x/a:

$$\left[\frac{x}{a}\right] = [T^2] \equiv [E \cdot T], \tag{66}$$

we propose that the fundamental relationship defining mass can be rewritten as:

$$m = -kS, \tag{67}$$

where action S encapsulates the elastic response of spacetime to force, k represents the effective elastic modulus of the vacuum along the relevant deformation mode , and the negative sign reflects the restoring nature of the elastic response. It expresses that mass reflects the temporal accumulation of resistance to deformation in the vacuum's elastic-dissipative lattice. This formulation coheres with the earlier identification of gravitational stiffness via $\zeta_{\mu\nu}$ and can be generalized as a contraction between the stress and strain tensors:

$$m \sim \zeta_{\mu\nu}\mathcal{G}^{\mu\nu}$$

VI. DERIVATION OF FUNDAMENTAL PARAMETERS OF ELECTROMAGNETIC FIELD

A. Fundamental parameters of the electromagnetic field

Building on the interpretation of mass as an elastic response of spacetime, we now explore how this formulation naturally leads to the derivation of electromagnetic field parameters. Since within our framework mass has dimensions of spacetime, and is given by $m = -k \cdot S$, we deduce that k must have dimensions of frequency. By substituting k with the quantum of angular frequency $\frac{c}{\lambda}$, and using Planck's constant h for the quantum of action, we obtain an expression of mass:

$$m = \frac{hc}{\lambda} \tag{68}$$

This equation directly links the energy of photons (or other quantum excitations) to mass, reinforcing Einstein's mass-energy equivalence from a fundamentally new perspective.

Now, note that:

- Substituting $\lambda = 1\ m$, corresponding to the characteristic scale of the unit quantum oscillator in our framework, we obtain the quantum of mass-energy for the electromagnetic field $m = \frac{hc}{1\ m}$.

- Dividing this quantum mass-energy by a volume $V = 1\ m^3$, and considering the linear frequency $\frac{c}{2\pi \cdot 1\ m}$ and linear momentum $\hbar = \frac{h}{2\pi}$ we obtain a quantum of mass density $\rho_{vac} = \frac{\hbar c}{2\pi \cdot 1\ m^4} \approx 5.03 \times 10^{-27}$ kg m^{-3} which is in excellent agreement with cosmological measurements from the Planck satellite mission [17].

- Finally, identifying the vacuum energy density as the Lagrangian density $\mathcal{L}$, and integrating over a unit four-volume $d^4x = 1\ m^4$, we recover the fundamental quantum of action $S = \int \mathcal{L}\ d^4x = \frac{\hbar c}{2\pi}$

VII. CONNECTION BETWEEN THE STEFAN-BOLTZMANN CONSTANT AND LONDON DISPERSION FORCES

In the framework developed here, we can connect the Stefan-Boltzmann constant σ to the fundamental constants describing vacuum fluctuations and intermolecular interactions, specifically the London dispersion (van der Waals) forces. This connection shows how blackbody radiation and quantum dispersion forces originate from a common underlying structure of vacuum fluctuations.

A. Stefan-Boltzmann Radiation and Its Dimensional Structure

The Stefan-Boltzmann law expresses the radiative energy flux density as:

$$R = \sigma T^4, \tag{69}$$

where R represents an energy flux per unit area, with dimensions of L^{-2} within our theoretical framework. The classical expression for Stefan-Boltzmann constant is:

$$\sigma = \frac{\pi^2 k_B^4}{60\hbar^3 c^2}\text{W m}^{-2}\text{K}^{-4} \tag{70}$$

This result shows that the Stefan-Boltzmann constant inherently carries a dependence on the structure of vacuum fluctuations. Within our framework, we have that $[\sigma] = [\mathrm{W\ m^{-2}K^{-4}}] \equiv [L^{-6}]$, and this $\frac{1}{r^6}$ dimensionality points strongly to the equations of quantum dispersion interactions.

B. London Dispersion Forces and Their Emergence from Vacuum Fluctuations

London dispersion forces arise from transient dipole-induced dipole interactions mediated by vacuum fluctuations of the electromagnetic field. The energy potential governing these interactions between two neutral molecules or atoms is given by:

$$U_{\mathrm{London}}(r) = -\frac{C_6}{r^6}, \tag{71}$$

where C_6 is a coefficient that depends on the polarizability of the interacting species and is ultimately linked to the structure of vacuum fluctuations.

At the microscopic level, London dispersion interactions decay as $\frac{1}{r^6}$ due to the localized nature of transient dipoles. However, in condensed matter systems, the cumulative effect of many such interactions modifies the overall scaling. When considering bulk materials, the total interaction energy per unit area between two solids exhibits a slower decay:

$$U_{\mathrm{bulk}}(r) \sim -\frac{C_6}{r^3}, \tag{72}$$

which reflects the summation of contributions over a macroscopic volume rather than individual dipole-dipole interactions.

C. Connecting Thermal Radiation to Dispersion Forces

We postulate, based on the scaling behavior and dimensional correspondence, that

$$U(r) = -\sigma \cdot C_6 \tag{73}$$

$$R = \sigma T^4 = \frac{\sigma C_6}{r^3}. \tag{74}$$

This equations propose that the radiative energy flux density arises as the macroscopic London dispersion interactions in bulk matter. In this analogy, thermal radiation arises as the coherent superposition of vacuum-induced dipole interactions across a macroscopic surface, with $T^4 \propto \frac{C_6}{r^3}$ encoding an effective dipole-density scaling.

Thus, the Stefan-Boltzmann constant does not merely reflect an empirical radiation law, but encodes the bulk thermodynamic response of an elastic quantum vacuum. Its microscopic origin in dispersion forces shows that both radiation and intermolecular interactions emerge from a common substrate: the fluctuation-dissipative structure of spacetime

D. Implications for the Unified Description of Vacuum Energy and Thermodynamics

The connection between Stefan-Boltzmann radiation and London dispersion forces highlights the profound relationship between thermal radiation, vacuum fluctuations, and the fundamental nature of space-time interactions. The Stefan-Boltzmann constant encapsulates the large-scale thermodynamic consequences of microscopic vacuum fluctuations, acting as an effective coupling constant between radiation and space-time structure. This result further supports the idea that the fundamental forces governing blackbody radiation, vacuum energy, and intermolecular interactions are unified under a common theoretical framework, wherein space-time itself exhibits elasticity-like properties encoded through its interaction with vacuum fluctuations.

E. Boltzmann Constant as a Relativistic Thermodynamic Force: A Unruh-Inspired Equality

Building on the reinterpretation of k_B as a thermo-entropic force (see Sec. IV C 3) and the fundamental equivalence introduced earlier (Eq. 46), we now propose a novel formulation of the Boltzmann constant as an emergent relativistic force.

Assuming the dimensional equivalence $1\,\mathrm{K} \equiv 1\,\mathrm{m} \equiv 1\,\mathrm{s}$ within our elastic vacuum framework, we express k_B as:

$$k_B = \frac{hc}{2 \cdot 1\,\mathrm{m}} \cdot \frac{1}{2\alpha \cdot 1\,\mathrm{s}} = \frac{E}{a} \tag{75}$$

In this expression, k_B acquires the form of a Newtonian-like force $F = ma$, with the following components:

- $\frac{hc}{1\,\mathrm{m}} \to m$: The characteristic energy scale of the vacuum, associated with a fundamental quantum of mass or photon energy.
- $\frac{1}{2\alpha \cdot 1\,\mathrm{s}} = \frac{\gamma}{1\,\mathrm{s}} \to a$: An effective proper acceleration, where the Lorentz-like factor $\gamma = \frac{1}{2\alpha}$

encodes the vacuum's resistance to excitation.

Thus, the Boltzmann constant k_B emerges as a quantized force scale, representing the vacuum's intrinsic responsiveness to acceleration. In this interpretation, entropy and temperature arise from the inertial resistance of spacetime to deformation, with k_B capturing the proportionality between energetic input and induced entropic curvature.

This Unruh-inspired formulation reinforces the view that thermodynamic quantities—such as temperature, and heat—are fundamentally geometric in nature. Here, k_B bridges the gap between thermal response and relativistic motion, playing a role analogous to that of G or μ_0 in mediating the vacuum's reaction to mass or charge, respectively. In this sense, k_B can be viewed as the *thermo-entropic stiffness constant* of spacetime: a universal coupling between acceleration, information flow, and thermal excitation. This perspective helps unify quantum field theory, thermodynamics, and general relativity within a common elastic-dynamical substrate.

VIII. PROPOSAL OF A NEW FIELD MODE: THE GRAVITO-ENTROPIC FIELD

The plausibility of a structured field theory uniting gravitational and entropic dynamics is supported by a range of independent theoretical and empirical findings:

- **Gravitational wave observations**, notably those by LIGO and Virgo, confirm that the gravitational field $\vec{g}$ can vary with time [41]. This supports the existence of dynamical couplings with an auxiliary field $\vec{T}$, where temporal variations in the entropic sector may induce circulation-like components in $\vec{g}$.
- **Black hole thermodynamics** reveals deep links between gravitational phenomena and thermodynamic quantities such as entropy and temperature [42, 43], supporting the idea that the entropic field $\vec{T}$ is not a derivative phenomenon, but rather a fundamental component of spacetime structure.
- **Experimental confirmations of gravitomagnetic effects**, such as those from Gravity Probe B [44], show that rotating masses generate a field component dependent on mass currents. This behavior is consistent with the idea that a circulating mass flow $\vec{J}_m$ contributes to the generation of a complementary field $\vec{T}$, in analogy with magnetism.
- **Thermodynamic derivations of gravitational dynamics**, such as Jacobson's approach to Einstein's equations [10] and Verlinde's emergent gravity framework [11], suggest that gravity may arise from underlying entropic principles.
- **Thermoelectric relationships** further strengthen the proposal. In condensed matter physics, temperature gradients generate electric potentials (Seebeck effect), while electric currents produce or absorb heat (Peltier effect) [45]. These two-way couplings between energy and entropy mirror the kind of mutual interactions expected in a gravito-entropic field theory. Additionally, the Unruh effect shows how temperature can emerge from acceleration, reinforcing the connection between thermodynamics and spacetime structure.

As we will see, a natural way to formalize the interplay between gravity and entropy in the fabric of spacetime is through the introduction of a *gravito-entropic field pair* $\{\vec{g}, \vec{T}\}$, where $\vec{g}$ represents the gravitational field and $\vec{T}$ denotes a thermo-entropic field, which does not denote temperature *per se*, but a circulating thermo-entropic field analogous to the magnetic field, generated by mass currents rather than charge. We coin the name *gravito-entropic* to reflect the intrinsic duality between radial mass-induced effects (gravity) and azimuthal thermo-entropy-induced circulation (thermo-entropic fields), both encoded in the elastic response of spacetime. In the following sections, we will construct a concrete theoretical framework supporting the emergence of this gravito-entropic pair, and detailing its precise mathematical relationship with the electromagnetic pair $\{\vec{E}, \vec{B}\}$.

Importantly, we will demonstrate that these two field pairs are not independent structures, but are instead related via a *modal scaling symmetry or projective geometric correspondence.* This scalar correspondence will show that $\vec{g}$ and $\vec{T}$ are alternative excitations—radial and azimuthal respectively, just as $\vec{E}$ and $\vec{B}$ do in the electromagnetic sector—of the same elastic substrate of spacetime from which electromagnetism also arises. Their geometric structure, scaling behavior, and source terms mirror those of $\vec{E}$ and $\vec{B}$, thus reinforcing the central thesis of this theory: *all fundamental fields are modal projections of a single symmetric deformation tensor $\mathcal{G}_{\mu\nu}$, with observed differences arising from symmetry, geometry, and coupling hierarchy.*

IX. A DEEP DIVE ON THE GRAVITO-ENTROPIC FIELD FUNDAMENTALS

Based on the similarities between the electromagnetic pair $\{\vec{E}, \vec{B}\}$ and the proposed gravito-entropic pair $\{\vec{g}, \vec{T}\}$, we propose a system of field equations mirroring Maxwell's equations. The gravitational field plays the role of the electric field, while the entropic field assumes the role of the magnetic field.

Below can be found a table summarizing the main derivations and relationships:

Quantity	**Electromagnetism**	**Gravito–entropic**
Source	Electric charge (q)	Mass (m)
Main field (circulatory)	$\vec{B} = \dfrac{\mu_0 \vec{I}}{2\pi r}\hat{\theta}$	$\vec{\mathcal{T}} = \dfrac{k_B \vec{I}_m}{2\pi r}\hat{\theta}$
Derived field (radial)	$\vec{E} = \dfrac{K_e Q}{r^2}\hat{r}$	$\vec{g} = \dfrac{G M}{r^2}\hat{r}$
Coupling constant	μ_0	$k_B = \mu_0/c^2$
Gauss's law	$\nabla \cdot \mathbf{E} = 4\pi K_e \rho_q$	$\nabla \cdot \mathbf{g} = -4\pi G \rho_m$
No-monopole law	$\nabla \cdot \mathbf{B} = 0$	$\nabla \cdot \mathcal{T} = 0$
Faraday's law	$\nabla \times \mathbf{E} = -\dfrac{\partial \mathbf{B}}{\partial t}$	$\nabla \times \mathbf{g} = -\dfrac{\partial \mathcal{T}}{\partial t}$
Ampère–Maxwell law	$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \dfrac{\partial \mathbf{E}}{\partial t}$	$\nabla \times \mathcal{T} = k_B \mathbf{J}_m + k_B \varepsilon_0 \dfrac{\partial \mathbf{g}}{\partial t}$

TABLE II. Comparison of Maxwell-like laws for electromagnetism and the proposed gravito–entropic sector.

Here, $\vec{I}_m$ and ρ_m respectively represent mass current and mass density. The product $k_B\varepsilon_0 = \frac{1}{c^4}$ plays a central role in the dynamic coupling of the gravito–entropic field, appearing as the analog of $\mu_0\varepsilon_0$ in electromagnetism. It determines the propagation response of $\vec{g}$ under temporal variations of the entropic field $\vec{\mathcal{T}}$, and encodes the universal stiffness of the vacuum to longitudinal, thermo–entropic excitations. Remarkably, this product can also be written as $k_B\varepsilon_0 \equiv \hbar/\mathrm{m}^2$, suggesting that the minimal entropic deformation of the vacuum carries a quantized action density. This reinforces the interpretation of $k_B\varepsilon_0$ as a modal invariant of the elastic vacuum: a fundamental coupling constant linking action, entropy, and geometry in the thermo-entropic sector.

A. Fundamental parameters of the gravito-entropic field

From our proposal, we can derive the fundamental parameters of the gravito-entropic field just dividing the parameters obtained for the electromagnetic field by c^2:

- We obtain the quantum of mass-energy for the gravito-entropic field $m_{entr} = \frac{\hbar}{2\pi c \cdot 1\ m} \approx 5.6 \times 10^{-44}$ kg.
- We obtain a quantum of mass density $\rho_{entr} = \frac{\hbar}{2\pi c \cdot 1\ m^4}$ kg m^{-3}.
- Setting the action $S = \int \mathcal{L}\ d^4x$ and substituting $\mathcal{L}$ with the quantum of mass density ρ_{entr}, and dx with $1\ m$, one gets the quantum of action $S = \frac{\hbar}{2\pi c}$.

B. Further justification of the parameters derived: Einstein-Hilbert action and Unruh effect

There are several checks that we can perform to further justify the validity of the fundamental parameters derived for the gravito-entropic field. In this subsection, we will focus on showing that the action obtained for the gravito-entropic field aligns with Einstein-Hilbert action, and that the Unruh effect can be directly derived from the application of the fundamental expression of mass-energy for the gravito-entropic field and Newton's Law.

1. *Derivation of the gravito-entropic action as the Einstein-Hilbert Action*

In a non-relativistic setting, an *action* S can be viewed as the time integral of the total energy (or, more precisely, the Lagrangian). In special relativity or general relativity, this idea generalizes to integrating a *Lagrangian density* $\mathcal{L}$ over the entire spacetime volume. Formally,

$$S = \int \mathcal{L}\sqrt{-g}\,d^4x, \tag{76}$$

where $g = \det(g_{\mu\nu})$ is the determinant of the metric tensor $g_{\mu\nu}$. The factor $\sqrt{-g}$ ensures *general covariance* of the volume element, making the action a scalar under coordinate transformations.

The Einstein-Hilbert action [46] [47] [4] in General Relativity with a cosmological constant is typically expressed as:

$$S_{EH} = \frac{c^4}{16\pi G}\int (R-2\Lambda)\sqrt{-g}\,d^4x \tag{77}$$

We can equate the Einstein-Hilbert action with cosmological constant to the general equation of action we have defined as:

$$S_{\rm EH} = \int \mathcal{L}\sqrt{-g}\,d^4x = \frac{c^4}{16\pi G}\int (R-2\Lambda)\sqrt{-g}\,d^4x \tag{78}$$

We can substitute the cosmological constant Λ via

$$\Lambda = 8\pi G\,\frac{\rho_{\rm vac}}{c^2}, \tag{79}$$

Assuming a De Sitter universe [48] [49], one can substitute $R = 4\Lambda$ and (79) to obtain that

$$\begin{aligned} S_{\rm EH} &= \frac{c^4}{16\pi G}\int \big(R-2\,\Lambda\big)\sqrt{-g}\,d^4x \\ &= \frac{c^4}{16\pi G}\int 2\,\Lambda\sqrt{-g}\,d^4x \\ &= \frac{c^4}{16\pi G}\int \frac{16\pi G}{c^2}\cdot\rho_{vac}\sqrt{-g}\,d^4x \\ &= \int \rho_{vac}\cdot c^2\sqrt{-g}\,d^4x \end{aligned} \tag{80}$$

Therefore, we identify the Lagrangian density $\mathcal{L}$ with the energy equivalent to vacuum energy density

$$\mathcal{L} \equiv \rho_{\rm vac}c^2 \tag{81}$$

Substituting ρ_{vac} with the expression obtained for the vacuum energy density (VI A), we have that

$$\rho_{\rm vac}c^2 = \frac{\hbar c}{2\pi\ 1\ m^4}c^2 = \frac{\hbar c^3}{2\pi\ 1\ m^4} \tag{82}$$

In an almost flat universe, spacetime is only slightly curved, and the metric tensor $g_{\mu\nu}$ deviates minimally from the flat Minkowski metric $\eta_{\mu\nu}$. Therefore, the determinant of the metric tensor g can be expressed as:

$$\sqrt{-g} \approx 1 + \frac{1}{2}\delta g. \tag{83}$$

For practical purposes in an almost flat universe, δg is so small that $\sqrt{-g} \approx 1$ is a valid approximation.

Recall that we have established that the fundamental measure of the system in the electromagnetic mode is $\tau = \frac{1\ s}{c} \equiv \frac{1\ m}{c}$. As a result, substituting, one gets that

$$S_{EH} = \frac{\hbar c^3}{2\pi\ 1\ m^4}\cdot\frac{1\ m^4}{c^4} = \frac{\hbar}{2\pi c} \tag{84}$$

Our derivation of the Einstein-Hilbert action demonstrates the potential of our common field model (and the postulated gravito-entropic field) to unify gravity, general relativity, and quantum mechanics. Evaluated over a nearly flat, vacuum-dominated universe, the action naturally yields our theoretical value $\frac{\hbar}{2\pi c}$ (IX A).

2. Deriving Unruh effect from the gravito-entropic field parameters and Newton's law

The **Unruh effect** [50] states that an observer with constant proper acceleration a in vacuum perceives a thermal bath at a temperature

$$T_{\rm Unruh} = \frac{\hbar\,a}{2\pi\,c\,k_B}. \tag{85}$$

Rearranging gives

$$k_B = \frac{\hbar\,a}{2\pi\,c\,T_{\rm Unruh}}. \tag{86}$$

We have already shown how k_B can be treated dimensionally as a force (IV C 3). Also, we have postulated that the expression of mass-energy for the gravito-entropic field is $m_{entr} = \frac{\hbar}{2\pi c\cdot\lambda}$. Using the equivalence $[L] \equiv [T_{emp}]$, we can easily see that the equation of the Unruh effect can be rewritten as

$$k_B = m_{entr}\cdot a \tag{87}$$

Showing how Unruh's effect can be derived from the application of Newton's law to the derived parameters of the gravito-entropic field.

C. Conclusion

The above derivations provide strong evidence that justify the existence of the gravito-entropic field. The Einstein-Hilbert action, traditionally rooted in curvature, emerges naturally as the action of the gravito-entropic field, and Unruh effect is just the manifestation of Newton's Law. This framework provides new insight into the gravito-entropic origins of gravity and suggests avenues for further exploration into quantum gravity and spacetime thermodynamics.

Part IV: Unified Field Theory from a Symmetric Deformation Tensor

X. THE SYMMETRIC FUNDAMENTAL TENSOR $\mathcal{G}_{\mu\nu}(x)$

Building on the elastic interpretation of the quantum vacuum proposed in Parts I–III, and the dimensional unification $[M] = [L] = [T]$, the most reasonable theoretical framework that we can propose given our results is that all classical fields are emergent modes of a single, symmetric rank-2 field tensor:

$$\mathcal{G}_{\mu\nu}(x)$$

This tensor encodes the local deformation of a Lorentz-invariant, elastic spacetime substrate. It generalizes the role of both the metric tensor in relativity and the electromagnetic potential in gauge theory. Rather than treating electric, magnetic, gravitational, and thermo-entropic fields as distinct fundamental entities, we interpret them as geometrically distinct projections or excitation modes of $\mathcal{G}_{\mu\nu}$. Thus, each physical interaction would correspond to a different symmetry-breaking or geometric configuration within this unified field.

Interestingly, this projection-based interpretation of field emergence aligns conceptually with recent work by Partanen and Tulkki [51], who propose a unification framework where gravity arises from four coupled $U(1)$ gauge symmetries. In their approach, the spacetime metric is not taken as a fundamental structure but rather emerges from the modal structure of gauge fields defined on a flat background. Analogously, in our model, the symmetric deformation tensor $\mathcal{G}_{\mu\nu}$ encodes the elastic response of the quantum vacuum, whose radial and azimuthal modal projections manifest as the electromagnetic and gravito-entropic fields, respectively. This supports the idea that observable interactions are not independent fields but manifestations of deeper symmetry modes of the vacuum.

XI. PROPOSAL OF FIELD MODES AND ITS INTERPRETATION

Within the proposed unified framework, fundamental fields derived from distinct physical interactions exhibit a similar structure modulated by dimensionless factors derived from the theory. Specifically, the electric field ($\vec{E}$), magnetic field ($\vec{B}$), gravitational field ($\vec{g}$), and the thermo-entropic field ($\vec{T}$) (VIII) arise based on the derivations within this framework, and take the form:

$$\begin{aligned}
(i)\quad & \vec{E} = \frac{e}{4\pi\varepsilon_0 r^2}\hat{r} \equiv \frac{2\alpha\cdot\mu_0 c^2}{c^2\cdot 4\pi\cdot r}\hat{r} = 2\alpha\cdot\frac{\mu_0}{4\pi r}\hat{r}\\
(ii)\quad & \vec{B} = \frac{\mu_0 I}{4\pi r}\hat{\theta} = \frac{\mu_0\cdot c}{4\pi\cdot r}\hat{\theta} = c\cdot\frac{\mu_0}{4\pi r}\hat{\theta} \equiv \frac{\vec{E}\cdot c}{2\alpha}\\
(iii)\quad & \vec{g} = \frac{Gm}{r^2}\hat{r} \equiv \frac{\mu_0\alpha^2\cdot\hbar c}{r^2\cdot 2\ m}\hat{r} \equiv \alpha^2\cdot\frac{hc}{1\ m^2}\cdot\frac{\mu_0}{4\pi r}\hat{r}\\
(iv)\quad & \vec{T} = \frac{k_B\cdot 2\alpha\cdot I}{4\pi r}\hat{\theta} = \frac{2\alpha}{c^2}\cdot\frac{\mu_0}{4\pi r}\hat{\theta} \equiv \frac{\vec{g}\cdot c}{2\alpha}
\end{aligned} \tag{88}$$

where we have used $e = \frac{2\alpha\cdot 1\ C}{c^2}$, $m = \frac{\hbar c}{2\cdot 1\ m}$ (VI A), $I = c$ (electromagnetic mode) and $I = \frac{1}{c}$ (gravito-entropic mode), together with the equivalences of (7).

Note that all the static fields adopt the generic form

$$\vec{\Phi}_X(r) = \frac{\mu_0}{4\pi r}\cdot C_X\cdot\hat{e}_X,$$

where $X \in \{E, B, g, T\}$ and C_X is a dimensionless coefficient. The direction $\hat{e}_X$ indicates the field's spatial orientation — either radial or azimuthal.

In this formulation, the characteristic expressions for the fundamental fields are constructed from the elementary contribution of discrete quantum oscillators. The magnetic field, for instance, is not derived from the standard expression for an infinite wire ($\vec{B} = \mu_0 I/2\pi r$), but rather from the Biot–Savart law applied to a localized oscillatory mode, yielding the expression $\vec{B} = \mu_0 I/4\pi r$, which better reflects the point-like, modular nature of the vacuum excitations in this framework. The mass m has been taken from the zero-point energy associated with a confined quantum harmonic oscillator mode of the vacuum, becoming an emergent quantity from the fundamental vacuum oscillation modes. This aligns with the conception of mass as a localized deformation in some elastic medium, and the unification of field modes under a shared geometric and dynamical substrate.

The patterns of the fields can be observed in the following summarizing table:

Field	Expression	Constant	Scaling	Direction
$\vec{E}$	$\frac{2\alpha}{4\pi}\cdot\frac{\mu_0}{r}\hat{r}$	$\frac{2\alpha}{4\pi}$	c^0	Radial $\hat{r}$
$\vec{B}$	$\frac{c}{4\pi}\cdot\frac{\mu_0}{r}\hat{\theta}$	$\frac{1}{4\pi}$	c^1	Acimutal $\hat{\theta}$
$\vec{g}$	$\frac{\alpha^2\cdot hc}{4\pi\ 1\ m^2}\cdot\frac{\mu_0}{r}\hat{r}$	$\frac{\alpha^2}{4\pi}$	c^{-3}	Radial $\hat{r}$
$\vec{T}$	$\frac{2\alpha}{4\pi c^2}\cdot\frac{\mu_0}{r}\hat{\theta}$	$\frac{2\alpha}{4\pi}$	c^{-2}	Acimutal $\hat{\theta}$

TABLE III. Proposed hierarchy of unified field modes.

where we have used $\frac{\hbar}{1\ m^2} \propto \frac{1}{c^4}$ (24) to derive the scaling of $\vec{g}$.

This refined formulation reveals that all four field expressions share a universal structural factor:

$$\frac{\mu_0}{4\pi r}$$

which can be interpreted as the universal elastic modulus of the vacuum. This quantity encapsulates the intrinsic coupling between elastic excitations and physical sources such as charge, mass, and temperature. Notably, this coupling is not arbitrary: using our fundamental identity (46)

$$\mu_0 \cdot e \equiv \frac{h \cdot c}{1\ m},$$

one can easily derive

$$\frac{\mu_0}{4\pi} = \frac{\hbar c}{2 \cdot 1\ m \cdot e} = \frac{E_0}{e},$$

where $E_0 = \hbar c/(2 \cdot 1\ m)$ is identified as the zero-point energy of a fundamental oscillator mode of the vacuum, and simultaneously interpreted as the rest mass energy associated with a unit deformation cell. This expression encodes $\mu_0/4\pi$ as some *fundamental vacuum deformation*, intrinsic to all field excitations and independent of the specific interaction, akin to some *deformation current*: the amount of vacuum energy deformation (in the form of rest mass) per unit of charge. In this sense, it quantifies the vacuum's elastic response rate to localized sources—be they of electric or gravitational nature. And thus, we will show in the next subsection how it can be related naturally to the fundamental solution (Green's function) of the Poisson equation in three dimensions.

A. Spectral Origin of Field Modes: Discrete Laplacian and Vacuum Structure

The fundamental solution (Green's function) of the Poisson equation in three dimensions is given by:

$$\nabla^2\Phi(\mathbf{r}) = -\delta^{(3)}(\mathbf{r}) \quad \Longrightarrow \quad \Phi(\mathbf{r}) = \frac{1}{4\pi r}.$$

This solution represents the field response to a point source and serves as the foundation for the ubiquitous prefactor

$$\frac{\mu_0}{4\pi r}$$

that appears in all unified field expressions. To formalize the connection with the elastic lattice model, we can move from this continuous description to a discretized Laplacian operator defined on a cubic lattice representing the vacuum.

Eigenstates of the Discrete Laplacian and Identification of Physical Modes

In a three-dimensional lattice, the Laplacian operator can be discretized, and its eigenstates (or proper modes) $\phi_n(\mathbf{r})$ satisfy the eigenvalue equation:

$$\nabla^2_{\text{disc}}\phi_n(\mathbf{r}) = -\lambda_n\phi_n(\mathbf{r}),$$

where λ_n denotes the spectrum of eigenvalues. We propose that physical field modes are not arbitrary deformations, but correspond to specific linear combinations of these fundamental eigenstates:

- **Radial Modes** $(\vec{E}, \vec{g})$: These fields, characterized by spherical symmetry, correspond to Laplacian eigenstates with radial symmetry. In the continuum limit, they naturally recover the $1/r$ profile.
- **Azimuthal Modes** $(\vec{B}, \vec{T})$: These fields represent torsional or circulatory deformations and correspond to eigenstates with rotational (vortical) symmetry. The degeneracy in the eigenvalue spectrum for these modes may be responsible for the emergence of local gauge symmetries, providing a rationale for how a symmetric fundamental tensor $\mathcal{G}_{\mu\nu}$ can give rise to derived antisymmetric force fields, as discussed in Section XIII B.

Eigenvalues as Geometric Origin of Physical Constants

The identification of the physical field modes with eigenstates of the discrete Laplacian allows us to interpret the eigenvalues λ_n as geometric stiffness coefficients of the vacuum lattice. Importantly, these eigenvalues are not arbitrary: their degeneracies and ratios encode internal symmetries among field sectors.

In particular, the observed structure of the unified fields reveals a remarkable hierarchy: each *azimuthal* field mode $(\vec{B}, \vec{T})$ emerges as a rescaled counterpart of its corresponding *radial* field mode $(\vec{E}, \vec{g})$ through a universal scaling factor:

$$\vec{B} = \frac{c}{2\alpha}\vec{E} = \gamma \cdot c \cdot \vec{E}, \qquad \vec{T} = \frac{c}{2\alpha}\vec{g} = \gamma \cdot c \cdot \vec{g},$$

where $\gamma = 1/(2\alpha)$ is a fundamental attenuation factor within the unified framework. This scaling relation strongly suggests that the eigenstates corresponding to $\vec{B}$ and $\vec{T}$ share eigenvalues λ_n that are degenerate or related by symmetry transformations (e.g., spherical-to-azimuthal coordinate rotations) with those of $\vec{E}$ and $\vec{g}$, respectively.

Moreover, across field sectors, deeper modal symmetries are observed. The gravitational and entropic modes can be expressed as attenuated forms of their electromagnetic analogs:

$$\vec{g} = \frac{\alpha}{c^3}\vec{E}, \qquad \vec{T} = \frac{\alpha}{c^3}\vec{B}.$$

These cross-sector scaling laws indicate that the gravito-entropic sector corresponds to lower-energy, coarse eigenmodes of the Laplacian spectrum—those with smaller eigenvalues λ_n—while the electromagnetic sector arises from higher-frequency excitations. Conversely, one can interpret $\vec{E}$ and $\vec{B}$ as relativistically amplified versions of $\vec{g}$ and $\vec{T}$:

$$\vec{E} = c^2 \cdot \vec{T}, \qquad \vec{B} = \alpha^2 \cdot \frac{h}{1\ \mathrm{m}^2} \cdot \vec{g},$$

pointing to a unified origin for all four fields as eigenmodes with distinct symmetry, energy scale, and deformation directionality. This modal hierarchy mirrors the spectral organization of Laplacian eigenfunctions on a discrete elastic lattice, where fundamental symmetries (radial, azimuthal, gauge) determine the degeneracy and structure of the eigenvalue spectrum.

From this perspective, the universal prefactor

$$\frac{\mu_0}{4\pi r}$$

found in all field expressions becomes the discrete-space analog of the Green's function solution to the Laplacian equation, encoding the vacuum's elastic response to a localized unit excitation. The dimensionless coefficients C_X thus act as modal weights tied to the eigenfunctions ϕ_n selected by the source's geometry and symmetry.

This synthesis supports a deeper interpretation: the symmetric tensor $\mathcal{G}_{\mu\nu}$ encodes all vacuum deformation modes, whose physical projections $\mathcal{G}^{(X)}$ (XIII A) arise from orthogonal components with distinct symmetry (e.g., $\mathcal{G}_{00}$ for radial compression, $\mathcal{G}_{0i}$ for torsion, $\mathcal{G}_{ij}$ for volumetric shear) (XIII B). The eigenvalue spectrum λ_n determines both the propagation and coupling strength of each mode, while the observed field symmetries arise from the degeneracy patterns and symmetry classes of the Laplacian eigenfunctions.

In summary, the hierarchy of physical fields observed in the unified theory—radial versus azimuthal, electromagnetic versus gravito-entropic—is rooted in the spectral geometry of the discrete Laplacian on the vacuum lattice. Each field is a modal projection of the elastic deformation tensor $\mathcal{G}_{\mu\nu}$, characterized by its eigenfunction class, coupling coefficient, and orientation. These relations not only consolidate the geometric unity of the theory, but also establish the Laplacian as the fundamental generator of the spacetime excitation spectrum.

Conceptual hierarchy of the unified field formulation

Having established the modal decomposition of the unified tensor and its associated field expressions, to provide a dynamical description of these modal excitations, we now introduce a minimal scalar field model that captures the essential propagation features of vacuum deformations. Each modal field—such as $\vec{E}$, $\vec{B}$, $\vec{g}$, or $\vec{T}$—can be represented by an effective scalar field Φ whose dynamics encode the energy balance between time and space variations. This model serves as a bridge between the oscillatory behavior of the vacuum and the field equations derived from action principles.

Below we show the conceptual hierarchy of the unified field formulation that we will detail briefly throughout the next sections:

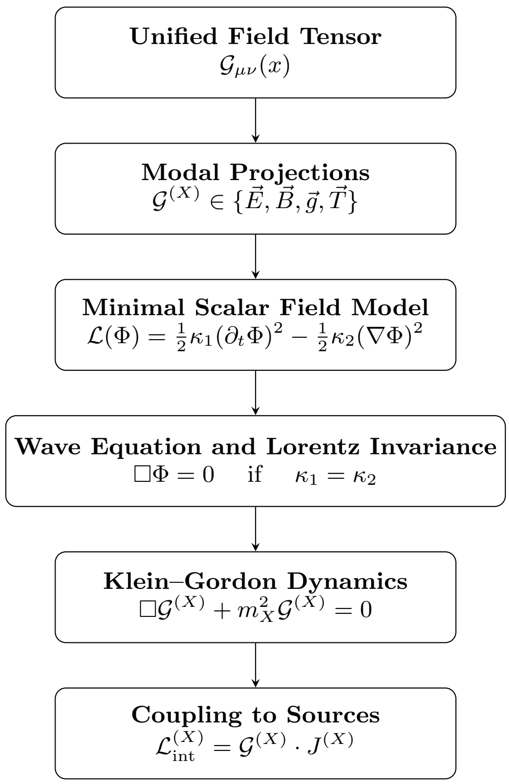

FIG. 1. Conceptual hierarchy of the unified field formulation: from geometric tensor structure to modal dynamics.

XII. MINIMAL SCALAR FIELD MODEL FOR MODAL EXCITATIONS

Let $\Phi(x)$ denote a *field* -in general, it can be a multi-component scalar, vector, or tensor, but for simplicity and illustrative purposes, we treat it here as a single real scalar field-. Include just the two couplings (or "rigidities") usual for harmonic oscillatory systems, κ_1 and κ_2, which can be reinterpreted as combinations of physical constants (e.g., ε_0, μ_0, G, k_B, etc.) under different substitutions depending on the mode of the elastic-oscillatory manifestation of the common field. Then, one can posit the following *minimal* Lagrangian density:

$$\mathcal{L}(\Phi) \;=\; \frac{1}{2}\,\kappa_1 \left(\partial_t\Phi\right)^2 \;-\; \frac{1}{2}\,\kappa_2 \left(\nabla\Phi\right)^2 \tag{89}$$

Here,

- κ_1 controls the inertial" or kinetic response of the field mode,
- κ_2 represents the elastic/spatial rigidity of the field mode.

The corresponding *action* S is given by the integral

$$S[\Phi] \;=\; \int d^4x \; \mathcal{L}\big(\Phi, \partial\Phi; \kappa_1, \kappa_2\big) \tag{90}$$

Applying the principle of least action, $\delta S = 0$, yields the Euler–Lagrange equation:

$$\kappa_1 \, \frac{\partial^2 \Phi}{\partial t^2} \;-\; \kappa_2 \, \nabla^2 \Phi \;=\; 0. \tag{91}$$

This *single* partial differential equation governs the field Φ. Depending on how we identify κ_i with physical constants and Φ with different spacetime deformations (e.g., mass, charge, temperature), we recover the different field modes.

A. Relativistic Compatibility and Spacetime Formalism

To ensure compatibility with special relativity, we introduce a four-dimensional spacetime coordinate:

$$X^\mu = \begin{pmatrix} t \\ x \\ y \\ z \end{pmatrix}, \quad \text{with metric} \quad \eta^{\mu\nu} = \mathrm{diag}(-1, 1, 1, 1). \tag{92}$$

We define the spacetime derivatives:

$$\partial_\mu = \frac{\partial}{\partial X^\mu} = \begin{pmatrix} \frac{\partial}{\partial t} \\ \frac{\partial}{\partial x} \\ \frac{\partial}{\partial y} \\ \frac{\partial}{\partial z} \end{pmatrix} \tag{93}$$

The standard Lorentz-invariant kinetic structure is encoded in the d'Alembertian operator:

$$\Box\Phi \equiv \eta^{\mu\nu}\partial_\mu\partial_\nu\Phi = -\frac{\partial^2\Phi}{\partial t^2} + \nabla^2\Phi. \tag{94}$$

The equation of motion from our minimal field Lagrangian reads:

$$\kappa_1 \frac{\partial^2\Phi}{\partial t^2} - \kappa_2 \nabla^2\Phi = 0. \tag{95}$$

To write this in a Lorentz-invariant form proportional to $\Box\Phi = 0$, we compare:

$$\kappa_1 \frac{\partial^2\Phi}{\partial t^2} = \kappa_2 \nabla^2\Phi \quad \Longrightarrow \quad \frac{\partial^2\Phi}{\partial t^2} = \frac{\kappa_2}{\kappa_1}\nabla^2\Phi. \tag{96}$$

Rewriting the d'Alembertian as:

$$\Box\Phi = -\frac{\partial^2\Phi}{\partial t^2} + \nabla^2\Phi = 0,$$

we see that Lorentz invariance requires:

$$\frac{\kappa_2}{\kappa_1} = 1 \quad \Rightarrow \quad \kappa_1 = \kappa_2. \tag{97}$$

Therefore, the field theory is manifestly Lorentz-invariant if and only if the rigidity constants match: $\kappa_1 = \kappa_2$. This ensures the action transforms as a scalar and the field equation becomes the standard wave equation:

$$\Box\Phi = 0. \tag{98}$$

Alternatively, one may directly enforce Lorentz invariance in the Lagrangian density by writing:

$$\mathcal{L}_{\mathrm{Lorentz}}(\Phi) = \frac{1}{2}\kappa, \eta^{\mu\nu}\partial\mu\Phi, \partial_\nu\Phi, \tag{99}$$

where κ encodes the rigidity of the mode and can later be matched to physical constants depending on the interpretation. In this more general framework, if one allows $\kappa_1 \neq \kappa_2$, the resulting dynamics describe propagation in a medium with anisotropic or symmetry-breaking features, which may be interpreted as emergent properties or effective behaviors in specific physical regimes (e.g., entropy-driven diffusion or gravitational strain), allowing the unified field to encompass richer phenomena under the same fundamental structure.

This scalar field model, though minimal, captures the essential dynamics of vacuum excitations. It shows how each modal projection of the unified field tensor $\mathcal{G}_{\mu\nu}$ can be described in terms of a wave-like field obeying Lorentz-invariant dynamics. This prepares the ground for a more detailed relativistic formulation in terms of Klein–Gordon dynamics and projection structures consistent with general relativity. In the following section, we generalize this framework to include mass terms, explicit coupling to sources, and consistent tensorial projections compatible with general relativity.

XIII. THEORETICAL FOUNDATIONS: KLEIN-GORDON DYNAMICS AND GENERAL RELATIVITY CONSISTENCY

A. Lagrangian framework for modal excitations

Building on the minimal scalar field formulation developed in the previous section —where each field mode Φ is governed by a Lorentz-invariant wave equation with equal coupling constants $\kappa_1 = \kappa_2$— we next extend this minimal setup to include mass terms and explicit source couplings, thus arriving at a Klein–Gordon-type framework that preserves Lorentz symmetry and aligns with general relativistic structure. This formulation extends the scalar model to allow modal excitations of the unified tensor $\mathcal{G}_{\mu\nu}$ to be described in terms of scalar, scalar-like, or contracted tensorial fields $\mathcal{G}^{(X)}$, each corresponding to a specific physical interaction (electric, magnetic, gravitational, or thermo-entropic).

For each such mode, we define the following canonical Lagrangian:

$$\mathcal{L}_X = \frac{1}{2}\partial^\mu \mathcal{G}^{(X)} \partial_\mu \mathcal{G}^{(X)} - \frac{1}{2} m_X^2 \left(\mathcal{G}^{(X)}\right)^2, \quad (100)$$

where $\mathcal{G}^{(X)}$ represents a projection of the full tensor $\mathcal{G}_{\mu\nu}$ along mode $X \in \{E, B, g, T\}$, and m_X is an effective mass scale associated with the deformation mode. This Klein–Gordon-type Lagrangian provides a Lorentz-invariant basis for describing both massless and massive field modes within the unified elastic framework.

The Euler–Lagrange equation yields:

$$\Box \mathcal{G}^{(X)} + m_X^2 \mathcal{G}^{(X)} = 0, \quad (101)$$

which reduces to the Klein–Gordon equation for free scalar propagation in Minkowski space.

Although the Lagrangian $\mathcal{L}_X$ describes free fields, coupling to physical sources can be incorporated via minimal interaction terms of the form:

$$\mathcal{L}_{\text{int}}^{(X)} = \mathcal{G}^{(X)}(x) \cdot J^{(X)}(x), \quad (102)$$

where $J^{(X)}$ is an effective source density corresponding to charge, mass, entropy flux, etc. These terms play an analogous role to the coupling $A_\mu J^\mu$ in electrodynamics. Since $\mathcal{G}^{(X)}$ represents a modal projection of the unified tensor $\mathcal{G}_{\mu\nu}$, the coupling is assumed to act only on the relevant scalarized or vectorial component associated with the physical mode.

A more general coupling scheme could link the full tensor to the energy–momentum content of matter via:

$$\mathcal{L}_{\text{int}} = \mathcal{G}_{\mu\nu}(x)\, T^{\mu\nu}(x), \quad (103)$$

from which each modal interaction $\mathcal{G}^{(X)} J^{(X)}$ would arise as a projection or contraction. This formulation ensures full compatibility with general relativistic coupling schemes.

B. Static solutions

In the static limit and for massless modes ($m_X = 0$), the equation (102) reduces to:

$$\nabla^2 \mathcal{G}^{(X)}(\vec{r}) = -J^{(X)}(\vec{r}), \quad (104)$$

with $J^{(X)}$ being an effective source term. For a point-like unit source located at the origin, $J^{(X)}(\vec{r}) = \delta^{(3)}(\vec{r})$, the Green's function solution is:

$$\mathcal{G}^{(X)}(r) = \frac{1}{4\pi r}. \quad (105)$$

Multiplying this fundamental response by a dimensionless coupling C_X and by the universal deformation factor μ_0 yields the physical field expression:

$$\boxed{\vec{\Phi}_X(r) = \mu_0 \cdot \frac{C_X}{4\pi r} \cdot \hat{e}_X} \quad (106)$$

as postulated in the unified field table of the previous section.

Each mode $\mathcal{G}^{(X)}$ can be formally extracted from the full tensor using projection operators $P^{\mu\nu}_{(X)}$ acting on $\mathcal{G}_{\mu\nu}$:

$$\mathcal{G}^{(X)}(x) := P^{\mu\nu}_{(X)}\, \mathcal{G}_{\mu\nu}(x), \quad (107)$$

ensuring that the decomposition is orthogonal, complete, and compatible with spacetime symmetries.

Projected Field Modes and Geometric Interpretation of $\mathcal{G}_{\mu\nu}$

We propose that the field $\mathcal{G}_{\mu\nu}$ is symmetric and real, with ten independent components:

- $\mathcal{G}_{00}$ encodes scalar deformations (electrostatic, gravitational).
- $\mathcal{G}_{0i}$ encodes torsional modes (magnetic field analog).
- $\mathcal{G}_{ij}$ represents spatial-shear or volume modes (gravitational and thermo-entropic analogs).

Their geometric meaning is determined by symmetry (e.g., spherical) and energy scale. Together, these components describe the elastic response of the vacuum to localized excitation. Each scalar field $\mathcal{G}^{(X)}$ is identified as a projection of a specific component or contraction of the unified tensor $\mathcal{G}_{\mu\nu}$, depending on symmetry and field geometry. Examples include:

$$\begin{aligned}\mathcal{G}^{(E)} &:= \mathcal{G}_{00},\\ \mathcal{G}^{(B)} &:= \sqrt{\mathcal{G}_{0i}\mathcal{G}^{0i}},\\ \mathcal{G}^{(g)} &:= \mathrm{Tr}(\mathcal{G}_{ij}),\\ \mathcal{G}^{(T)} &:= \sqrt{\mathcal{G}_{ij}\mathcal{G}^{ij}}.\end{aligned}$$

These choices reflect radial vs. azimuthal structure and are consistent with the interpretation of the fields as spatially oriented deformation modes. Although $\mathcal{G}^{(B)}$ and $\mathcal{G}^{(T)}$ are scalar in dynamics, the physical fields $\vec{B}$ and $\vec{T}$ acquire their azimuthal direction $\hat{\theta}$ through the geometric structure of the excitation mode (e.g., torsional boundary condition). This is analogous to standing wave patterns in elastic continua where mode functions are scalar but correspond to vectorial deformations.

A rigorous modal decomposition would require defining a complete set of orthogonal projection operators $P^{\mu\nu}_{(X)}$ that extract each physical mode from $\mathcal{G}_{\mu\nu}$. In this initial formulation, we adopt symmetry-guided identifications consistent with the observed field patterns, while leaving the development of a full operatorial decomposition to future refinement.

Emergence of Antisymmetric Excitations

Although the unified field $\mathcal{G}_{\mu\nu}$ is symmetric, antisymmetric field excitations—such as those encoded in the electromagnetic field tensor $F_{\mu\nu}$—can emerge as derived objects from its spacetime derivatives. Specifically, we define generalized field strengths:

$$F^{(X)}_{\mu\nu} := \partial_\mu \mathcal{G}^{(X)}_{\nu\rho} - \partial_\nu \mathcal{G}^{(X)}_{\mu\rho}, \tag{108}$$

where ρ is a fixed index associated with the geometric direction of deformation—typically radial ($\rho = 0$) for electric or gravitational modes, and azimuthal ($\rho = i$) for magnetic or entropic torsional analogs.

This construction reflects the idea that local antisymmetric excitations, such as rotational or torsional responses, arise as gradients or curls of symmetric deformations in an elastic continuum. In particular:

- For $X = E$, choosing $\rho = 0$ yields a generalized electric-type field strength.
- For $X = B$, choosing $\rho = i$ (azimuthal direction) produces magnetic-like curls.
- For $X = T$ and $X = g$, similar constructions could yield thermo-entropic and gravitodynamic vorticities, respectively.

This formalism embeds antisymmetric field behavior directly into the derivative structure of the symmetric tensor $\mathcal{G}_{\mu\nu}$. It suggests that classical field strengths $F_{\mu\nu}$, typically postulated as fundamental, may instead arise as secondary geometric quantities, traces of deeper symmetric modes of the quantum-elastic vacuum.

Furthermore, this opens a natural path to defining the field dynamics from an action principle involving scalar invariants of the form:

$$\mathcal{L}_X \sim F^{(X)}_{\mu\nu} F^{(X)\mu\nu},$$

which parallels the standard electromagnetic Lagrangian, but grounds it in the unified tensorial origin of $\mathcal{G}_{\mu\nu}$.

A rigorous generalization would involve introducing projection operators $P^{\mu\nu\rho}_{(X)}$ that select the appropriate contraction and symmetry structure for each field type, an avenue left open for future formal development.

C. Interpretation and consistency with General Relativity

The field components $\mathcal{G}^{(X)}$ can be seen as mode projections of a symmetric deformation tensor $\mathcal{G}_{\mu\nu}$, whose full dynamics, in the relativistic regime, would be governed by a generally covariant action:

$$S = \int \mathcal{L}_X \sqrt{-g}\, d^4x, \tag{109}$$

with $\mathcal{L}_X$ defined for each scalar excitation or composite tensorial contraction. For instance, the Einstein–Hilbert action

$$S_{EH} = \frac{c^4}{16\pi G} \int R \sqrt{-g}\, d^4x, \tag{110}$$

can be seen as a special realization where the Lagrangian is given by the Ricci scalar R derived from the underlying metric $g_{\mu\nu}$. To recover Einstein's equations from the unified field dynamics, we could identify the macroscopic metric as a coarse-grained average:

$$g_{\mu\nu}(x) = \langle \mathcal{G}_{\mu\nu}(x) \rangle. \tag{111}$$

This averaging would define an emergent Riemannian geometry whose curvature satisfies $G_{\mu\nu} = 8\pi G\, T_{\mu\nu}$ in the classical limit, and where $\langle\cdot\rangle$ denotes a coarse-grained or averaged value of the tensor field over microscopic vacuum excitations. It does not necessarily imply a full quantum expectation value, but rather a macroscopic effective field akin to a thermodynamic mean, acting as the geometric background in which the dynamics of the elastic field unfold. The Einstein–Hilbert action would then describe the large-scale behavior of this emergent average, not the full tensor field $\mathcal{G}_{\mu\nu}$ itself.

D. Field Modes as Standing Waves of the Elastic Vacuum

Each excitation $\mathcal{G}^{(X)}$ corresponds to a distinct deformation mode—radial or azimuthal—of the elastic vacuum. These modes behave as standing wave solutions of a field equation with spherical symmetry, and their spatial profiles naturally reflect this structure. Notably:

- The observed $1/r$ dependence of physical fields (such as $\vec{E}, \vec{B}, \vec{g}, \vec{T}$) arises directly from the Green's function of the Laplacian in three spatial dimensions [15], consistent with oscillatory responses in elastic and electromagnetic media.
- In the dimensional framework adopted here—where mass, charge, and temperature share the same fundamental dimension, $[M] \equiv [Q] \equiv [T_{\text{emp}}] \equiv [L]$—source terms such as mass or charge have dimension $[L]$, and thus expressions of the form *source*$/r^2$ acquire the overall dimension $[1/r]$. This implies that the radial decay of fields such as $\vec{E}$, $\vec{g}$, or $\vec{T}$ is dimensionally equivalent to $1/r$, even when expressed in terms of a traditional source-over-distance-squared structure.
- Moreover, by identifying the physical fields directly with the scalar field response $\mathcal{G}^{(X)}$ (rather than with its spatial derivatives), the model preserves the $1/r$ behavior of the fields without invoking an explicit divergence or gradient operation. This stands in contrast to conventional formulations, where vector fields decay as $1/r^2$ due to their derivative origin.

Despite the internal deformations encoded in $\mathcal{G}_{\mu\nu}$, Lorentz invariance is preserved at the level of the field equations. The field transforms covariantly, and the elastic vacuum is treated as a Lorentz-invariant medium whose excitations carry well-defined transformation properties under boosts and rotations.

A minimal covariant Lagrangian compatible with this framework—and reflecting the standard structure of a harmonic oscillator— could be:

$$\mathcal{L}_X = \frac{1}{2}\partial^\mu \mathcal{G}^{(X)} \partial_\mu \mathcal{G}^{(X)} - \frac{1}{2}\omega_X^2 (\mathcal{G}^{(X)})^2, \quad (112)$$

where ω_X is a mode-specific frequency scale determined by the underlying vacuum impedance for each deformation type X. This form encapsulates both the elastic (restoring) behavior and the propagation of each field mode, consistent with wave equations and classical oscillator dynamics. It also lays the foundation for quantization and mode decomposition in future developments.

Thus, the elastic field paradigm maintains both internal geometric coherence and external compatibility with the fundamental symmetries of relativistic field theory, while offering a unified geometric origin for all classical fields and their characteristic falloffs.

E. Outlook and Future Developments: Quantization and Gauge Extensions

Quantization of the unified field $\mathcal{G}_{\mu\nu}$ can naturally proceed via a covariant path-integral formalism:

$$Z = \int \mathcal{D}\mathcal{G}_{\mu\nu}\, e^{iS[\mathcal{G}_{\mu\nu}]}, \quad (113)$$

where the action S is built from Lorentz-invariant scalars involving $\mathcal{G}_{\mu\nu}$ and its derivatives. In this framework, each classical deformation mode $\mathcal{G}^{(X)}$ corresponds to a quantized normal mode of the elastic vacuum, analogous to phonons in condensed matter or gauge bosons in standard field theory. The vacuum behaves as a lattice of coupled quantum oscillators whose eigenmodes give rise to the familiar field excitations. This path-integral formulation provides a consistent platform for computing quantum amplitudes and propagators, and suggests that classical fields emerge as expectation values or coherent states of quantized elastic modes.

Modal Symmetries and Gauge Generalizations.

While the present work focuses on classical modes corresponding to electromagnetic, gravitational, and thermo-entropic phenomena, further developments may incorporate internal symmetries and non-Abelian structures. In particular, *gauge fields*—such as those of the weak and strong interactions—could emerge as *internal connections or curvature forms* associated with symmetry groups acting on internal indices of $\mathcal{G}_{\mu\nu}$, or through matrix-valued generalizations of the field (e.g., $\mathcal{G}^a_{\mu\nu}$ with gauge index a).

Likewise, *fermionic matter fields* might arise via supersymmetric extensions of the framework, in which $\mathcal{G}_{\mu\nu}$ is embedded in a superfield whose components include spinorial partners. This opens the possibility of viewing matter as a localized defect or topological excitation in the elastic substrate, governed by the same underlying dynamics.

Path Forward.

These generalizations, while beyond the scope of the present paper, are structurally compatible with the elastic field paradigm and its modal decomposition. A fully developed theory would entail:

- Construction of the complete action functional $S[\mathcal{G}_{\mu\nu}]$ including source couplings, curvature terms, and possibly non-linearities;
- Identification of symmetry groups associated with different field sectors (Abelian, non-Abelian, supersymmetric);
- Quantization via canonical or path-integral methods, and the study of resulting propagators and interactions;
- Exploration of topological solutions and their identification with particle-like excitations.

Thus, while the present work lays the geometric and dynamic foundations, a richer landscape of quantum and gauge-theoretic structures awaits development within the same unified elastic framework.

Part VI: Cosmological implications of the established framework

XIV. THE COSMOLOGICAL CONSTANT Λ AND ITS RELATIONSHIP WITH THE GRAVITO-ENTROPIC FIELD

The Einstein field equation in its most general form, including the cosmological constant Λ, is:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu} \quad (114)$$

When there is no matter or conventional energy present, i.e., $T_{\mu\nu} = 0$, the Einstein field equation reduces to:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + \Lambda g_{\mu\nu} = 0 \quad (115)$$

In this case, Λ can be interpreted as a form of *intrinsic energy* of the vacuum, which acts as a source of spacetime curvature. This vacuum energy is present even in the absence of matter or radiation.

To describe the vacuum energy as a form of energy affecting the curvature of spacetime, we can reinterpret the term $\Lambda g_{\mu\nu}$ as contributing to an *effective energy-momentum tensor* for the vacuum energy. This gives us the following form for the vacuum energy-momentum tensor:

$$T^{\text{vac}}_{\mu\nu} = -\frac{\Lambda c^4}{8\pi G}g_{\mu\nu} \quad (116)$$

This term behaves like a *perfect fluid* with a constant energy density ρ_{vac} and an associated pressure p_{vac} related to the vacuum energy. The vacuum energy behaves like a fluid with *negative pressure*, meaning the pressure p_{vac} is equal to $-\rho_{\text{vac}}c^2$.

Then, the relationship between ρ_{vac} and Λ can be obtained by identifying the term describing vacuum energy in the Einstein field equation with the standard form of a perfect fluid in cosmology. In a universe dominated by vacuum energy, the effective energy density can be expressed as:

$$\rho_{\text{vac}}c^2 = \frac{\Lambda c^4}{8\pi G} \quad (117)$$

Operating, one has that

$$4\pi G\rho_{vac} = \frac{1}{2}\Lambda c^2 \quad (118)$$

which shows how the cosmological constant Λ is fundamentally tied to the gravitational flux as an expression of Gauss Law, with vacuum energy density ρ_{vac}, and a structure reminiscent of kinetic energy or Einstein's mass-energy equivalence formula. The right-hand side of the equation implies that Λ can be viewed as a scaling factor for the intrinsic gravitational flux associated with the vacuum.

From a thermodynamic perspective, this formulation resonates with the idea that gravity emerges from microscopic degrees of freedom, as suggested by holographic and entropic gravity approaches. The cosmological constant in this context can be interpreted as a measure of the equilibrium state of the vacuum, analogous to the way that temperature regulates thermodynamic systems. This perspective aligns with Jacobson's derivation of Einstein's equations from thermodynamic principles [10], where fluctuations in vacuum energy sustain an equilibrium that manifests macroscopically as gravitational dynamics.

Solving for Λ, we have that:

$$\Lambda = \frac{8\pi G \rho_{\mathrm{vac}}}{c^2} \tag{119}$$

Recall that, within our framework, vacuum energy density ρ_{vac} can be expressed (VI A) as:

$$\rho_{\mathrm{vac}} = \frac{\hbar c}{2\pi \cdot 1\,\mathrm{m}^4}. \tag{120}$$

Substituting (120) into (119), we obtain:

$$\Lambda = \frac{8\pi G}{c^2} \cdot \frac{\hbar c}{2\pi \cdot 1\,\mathrm{m}^4} = \frac{4G\hbar}{c \cdot 1\,\mathrm{m}^4}. \tag{121}$$

Dividing both sides by 4, we arrive at:

$$\frac{\Lambda}{4} = G \cdot \frac{\hbar}{c \cdot 1\,\mathrm{m}^4}. \tag{122}$$

A. Interpretation as an Equipartition Theorem

The right-hand side of (122) can be interpreted as an expression akin to the equipartition theorem. Recall that the equipartition theorem states that the average total energy of a harmonic oscillatory system is $k_B T$. Here, $G = k_B \cdot c^2 \cdot \alpha^2$ plays the role of a scaled Boltzmann constant k_B, and $\frac{\hbar}{c \cdot 1\,\mathrm{m}^4}$ represents the energy density associated with the gravito-entropic field (IX A). Thus, we can interpret that $\frac{\Lambda}{4}$ encodes the average energy density of the gravito-entropic field, distributed over the degrees of freedom of the spacetime lattice. This interpretation aligns with the idea that the cosmological constant arises from the quantum fluctuations of the vacuum, as predicted by quantum field theory.

B. Gravito–Entropic Action Density and the Geometric Structure of the Cosmological Constant

From (119), substituting some derived expressions for universal constants, we obtain several equivalent formulations of Λ. In particular, using $\rho_{\mathrm{vac}} = \frac{\hbar c}{2\pi \cdot 1\,\mathrm{m}^4} = \frac{1}{2\pi c^3 \cdot 1\,\mathrm{m}^2}$ from (**??**) and $G = \frac{1}{16\pi c}$ from (IV H), we arrive at:

$$\Lambda = 8\pi \cdot \frac{1}{16\pi c} \cdot \frac{1}{2\pi c^3 \cdot 1\ m^2} \cdot \frac{1}{c^2} = \frac{1}{4\pi c^6 \cdot 1\ m^2} \tag{123}$$

Recalling that the thermo-entropic modal action was shown to be $S_{\mathrm{th}} = \frac{\hbar}{c^2}$, we see that

$$\Lambda = \frac{S_{\mathrm{th}}}{4\pi \cdot 1\,\mathrm{m}^4}$$

This reveals a deep structural insight: the cosmological constant is not merely a phenomenological parameter but the manifestation of a universal *modal action density per 4D volume.* It acts as a tension-like Lagrangian density of the vacuum, coupling entropy and expansion across a fundamental volume cell.

Interpretation as Geometric Surface Tension

Indeed, note that setting $r = c^3 \cdot 1\ m$ situates Λ as an effective curvature density, with $4\pi r^2 = 4\pi c^6 \cdot 1\ m^2$ representing the "surface" of an expanding spherical volume. Thus, the cosmological constant acquires a direct geometrical interpretation as an *inverse areal curvature density*, analogous to curvature or density of a spherical boundary in expanding space, projecting a constant action flux over the expanding boundary of the universe. From this viewpoint, Λ is not a bulk energy density but a quantized surface effect—a geometric relic of the thermo-entropic elasticity of the vacuum.

This form provides a physical interpretation in which the large-scale expansion of the universe is driven by a steady energy flow that distributes itself over the expanding boundary, dynamically adjusting the effective curvature density as the volume of the universe grows. This interpretation not only aligns with the curvature requirements of an accelerating universe but also positions Λ as a fundamental invariant describing how the vacuum tension distributes minimal action quanta across areal elements, reinforcing the idea that the cosmological constant is, in essence, the *vacuum's curvature Lagrangian.*

Modal Structure of Λ: Field Strength Interpretation and Action Principle

The appearance of the factor $\frac{1}{4}$ in the expression for Λ [Eq. (122)] is not accidental—it matches the canonical structure of kinetic terms in gauge field Lagrangians, where the field strength is contracted to form a scalar:

$$\mathcal{L}_{\mathrm{EM}} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}. \tag{124}$$

Motivated by this analogy, we propose an effective gravito-entropic field strength tensor $\mathcal{F}^{(GE)}_{\mu\nu}$, derived from the projected modes of the symmetric deformation field $\mathcal{G}_{\mu\nu}$ (108):

$$\mathcal{F}_{\mu\nu}^{(GE)} := \partial_\mu \mathcal{G}_\nu^{(T)} - \partial_\nu \mathcal{G}_\mu^{(T)}, \tag{125}$$

where $\mathcal{G}_\mu^{(T)}$ represents an effective vector field associated with thermo-entropic modal projections of the vacuum (e.g., torsional or volumetric oscillations). The corresponding Lagrangian density for the gravito-entropic sector takes the form:

$$\mathcal{L}_{\mathrm{GE}} = -\frac{1}{4}\mathcal{F}_{\mu\nu}^{(GE)}\mathcal{F}^{(GE)\mu\nu}, \tag{126}$$

which naturally integrates into the total vacuum action. In this picture, the cosmological constant Λ arises as the average contraction:

$$\Lambda = \langle \mathcal{L}_{\mathrm{GE}} \rangle, \tag{127}$$

interpreted as the *modal energy density* of the vacuum associated with gravito-entropic fluctuations.

This unifies a geometric view of Λ as spacetime curvature with a field-theoretic interpretation grounded in tensor dynamics. In this framework, the cosmological constant ceases to be an arbitrary constant and instead emerges as a vacuum-averaged scalar—encoding the net effect of thermo-entropic field fluctuations projected from the underlying symmetric structure of spacetime.

Moreover, since the modal action density of the thermo-entropic field was shown to scale as $S_{\mathrm{th}} = \hbar/c^2$, the appearance of Λ as a contraction of field strength terms suggests that each minimal spacetime cell contributes a quantized action unit to the curvature of the vacuum. The cosmological constant thus acts as a macroscopic residue of these microscopic modal interactions—a kind of elastic equilibrium tension that encapsulates the thermodynamic state of the vacuum in a covariant formulation- and the effective Lagrangian density of an emergent field theory, derived from the symmetry-reduced oscillatory modes of an elastic and quantized vacuum substrate.

XV. A SCALE-DEPENDENT EFFECTIVE GRAVITATIONAL CONSTANT HYPOTHESIS FOR THE HUBBLE TENSION

A. Basis for Our Hypothesis

We have previously shown (see Section IV G) that the gravitational constant can be derived from the self-energy of a uniformly dense sphere, resulting in:

$$G = \frac{3}{5} 4\pi\varepsilon_0$$

On the other hand, consider the electrostatic energy stored in a charged spherical conductor of capacitance C and charge Q ([36]), given by:

$$U_{\mathrm{capacitor}} = \frac{1}{2}\frac{Q^2}{C} \tag{128}$$

For a sphere of radius r, the capacitance is $C_{\mathrm{sphere}} = 4\pi\varepsilon_0 r$, so the stored energy becomes:

$$U_{\mathrm{Glob}} = \frac{1}{2}\frac{e^2}{4\pi\,\varepsilon_0\, r}$$

This expression lacks the geometric self-energy term present in the self-energy case. If we derive the capacitance from the stored energy U_{Glob} and potential $V = \frac{1}{4\pi\varepsilon_0}\frac{e}{r}$ we find:

$$C = \frac{U_{\mathrm{Glob}}}{V^2} = 2\pi\varepsilon_0 r \quad \Rightarrow \quad \frac{C}{r} = 2\pi\varepsilon_0$$

This leads to a dual effective gravitational coupling framework:

- **Local Scales:** Characterized by significant inhomogeneity (e.g., galaxies and clusters), gravitational dynamics are modeled with an effective coupling

  $$G_{\mathrm{Loc}} = \frac{3}{5} 4\pi\varepsilon_0$$

  This value corresponds to the full self-interaction contribution and is identified with the standard Newtonian constant G_N.

- **Global Scales:** At cosmological scales, where the Universe is approximately homogeneous and isotropic, gravitational dynamics are governed by a reduced effective coupling

  $$G_{\mathrm{Glob}} = 2\pi\varepsilon_0$$

Physical Motivation: This hypothesis interprets the non-linearities of gravity—prominent in clumpy, small-scale environments—as contributing an additional self-energy component to the effective gravitational coupling, resulting in G_{Loc}. On very large scales, where the matter distribution is smooth, these nonlinear effects average out or become negligible, yielding an effective coupling closer to G_{Glob}. This scale dependence of the gravitational constant $G_{\mathrm{eff}}(z)$ is proposed as the underlying physical mechanism unifying the explanation of the *Hubble tension* and *dark sector* phenomena.

B. Self-Interaction Terms as the Source of Hubble Tension

As a result, our hypothesis posits that gravitational self-interactions manifest significantly at *local scales* (e.g., Cepheid-based distance ladders, Type Ia supernovae) where the inhomogeneous matter distribution leads to nonlinear gravitational effects. This corresponds to using G_{Loc}, which includes self-energy.

By contrast, *global scale* determinations (e.g., Planck measurements of the CMB, BAO analyses) probe the Universe on large, smoothed-out scales. Here, gravitational self-interactions become negligible, justifying the use of G_{Glob}.

This dichotomy explains the persistent discrepancy in H_0 values, known as the *Hubble tension.* The plausibility of the hypothesis can be checked using Friedmann equations [52] [53] [54]. The first Friedmann equation is given by:

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho_{\text{vac}} - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3}, \tag{129}$$

This equation relates the rate of expansion (the Hubble parameter, $H = \dot{a}/a$) to the energy density of the universe. Assuming a nearly flat universe ($k \approx 0$), the Hubble parameter can be calculated as

$$H^2 \; = \; \frac{8\pi\, G}{3}\,\rho_{\text{vac}} \; + \; \frac{\Lambda c^2}{3}\,,$$

Substituting with our previous expression for Λ (119), we have that

$$H^2 \; = \; \frac{8\pi\, G}{3}\,\rho_{\text{vac}} \; + \; \frac{\Lambda c^2}{3} = \frac{8\pi\, G}{3}\,\rho_{\text{vac}} \; + \; \frac{8\pi\, G \frac{\rho_{\text{vac}}}{c^2} c^2}{3} = 2\left(\frac{8\pi\, G}{3}\,\rho_{\text{vac}}\right) = \frac{16\pi\, G}{3}\,\rho_{\text{vac}}$$

Now, two regimes emerge naturally. Using $\rho_{\text{vac}} = \frac{\hbar c}{2\pi \cdot 1\; m^4}$ as we have derived for the electromagnetic field, we have that:

1. **Global Regime (no self-interactions):**

$$\begin{aligned} H_{\text{Glob}} &= \sqrt{\frac{16\pi G_{\text{Glob}}}{3}\rho_{\text{vac}}} \\ &= \sqrt{\frac{16\pi \cdot 2\pi\varepsilon_0}{3}\frac{\hbar c}{2\pi \cdot 1\; m^4}} \\ &\approx 2.165 \times 10^{-18}\,\text{s}^{-1} = 66.81\,\text{km/s/Mpc} \end{aligned} \tag{130}$$

This matches the CMB-based Planck 2018 measurement: $H_0 = 67.4 \pm 0.5\,\text{km/s/Mpc}$ [55].

2. **Local Regime (includes self-interactions):**

$$\begin{aligned} H_{\text{Loc}} &= \sqrt{\frac{16\pi G_{\text{Loc}}}{3}\rho_{\text{vac}}} \\ &= \sqrt{\frac{16\pi \cdot \frac{3}{5}4\pi\varepsilon_0}{3}\frac{\hbar c}{2\pi \cdot 1\; m^4}} \\ &\approx 2.3714 \times 10^{-18}\,\text{s}^{-1} = 73.17\,\text{km/s/Mpc} \end{aligned} \tag{131}$$

This matches the SH0ES result: $H_0 = 73 \pm 1.0\,\text{km/s/Mpc}$ [56].

C. Discussion and Observational Tests

Our framework predicts a mild but physically meaningful *scale–dependence* of the effective gravitational constant, reflecting the gradual transition between regimes with and without gravitational self-interactions. We predict that the Hubble parameter $H(z)$ evolves between two fixed values due to a scale-dependent gravitational constant:

$$\begin{aligned} &\lim_{z\to 0} H(z) \to H_{\text{Loc}} \approx 73\,\text{km/s/Mpc} \\ &\lim_{z\to\infty} H(z) \to H_{\text{Glob}} \approx 67\,\text{km/s/Mpc} \end{aligned} \tag{132}$$

This transition reflects a shift from nonlinear gravitational dynamics to homogeneous large-scale behavior. This interpretation leads to several concrete, testable consequences:

- **Redshift evolution:** As self-interaction effects dominate locally, we expect $G_{\text{eff}} \approx G_{\text{Loc}}$ at low redshifts, yielding a higher inferred Hubble constant $H(z \approx 0) \approx 73\,\text{km/s/Mpc}$. At higher redshifts—probing smoother, linear regimes—$G_{\text{eff}} \to G_{\text{Glob}}$, driving $H(z)$ down toward $\sim 67\,\text{km/s/Mpc}$. A continuous transition in $H(z)$ would strongly support our hypothesis.
- **Structure formation diagnostics:** A discrepancy between local and early-universe structure growth would corroborate scale-dependent gravitational dynamics.

D. Final Note: Theoretical Context and Consistency

Reconciling a scale-dependent G with General Relativity—which assumes a universal, constant gravitational coupling—requires careful consideration. *The presented model serves as an effective field theory*: standard General Relativity with Newton's constant G_N describes gravity accurately in the local, nonlinear regime (i.e., $G_{\text{Loc}} \equiv G_N$), while on cosmological scales, averaging over large volumes under homogeneity and isotropy leads to effective dynamics that resemble General Relativity but with a renormalized, scale-dependent coupling G_{Glob}. In this perspective, the Friedmann equations remain applicable because they emerge from the Einstein field equations under symmetry assumptions, and the modification resides not in the geometry, but in the coupling between geometry and energy-momentum.

XVI. SCALE-DEPENDENT VACUUM ENERGY AND IMPLICATIONS FOR THE DARK SECTOR

As derived in previous sections (123), we obtain a geometric expression for the cosmological constant:

$$\Lambda = \frac{1}{4\pi c^6 \cdot 1\,\text{m}^2}$$

Using the standard expression that relates the vacuum energy density to the cosmological constant:

$$\rho_{\text{vac}} = \frac{\Lambda c^2}{8\pi G}$$

we see that ρ_{vac} is inversely proportional to the gravitational coupling G. Since our framework posits that G is scale-dependent—shifting between G_{Loc} and G_{Glob} depending on the cosmic regime—then, *if c is constant, we have that ρ_{vac} is necessarily* scale-dependent *as well.*

A. Implications for Dark Energy

Traditionally, dark energy is interpreted as a constant vacuum energy density that drives the accelerated expansion of the Universe. In our framework, however, $\rho_{\text{vac}}(z)$ decreases at low redshifts as the effective gravitational coupling increases:

$$G(z) \uparrow \quad \Rightarrow \quad \rho_{\text{vac}}(z) \downarrow$$

This inverse relationship offers a reinterpretation of cosmic acceleration: it is not that vacuum energy increases over time, but rather that the weakening of gravitational interactions on cosmological scales (due to reduced self-interaction) makes the vacuum energy *appear* larger when interpreted through a globally averaged G. Hence, the dark energy component of the ΛCDM model may be an artifact of applying a scale-invariant coupling in a scale-dependent Universe.

B. Implications for Dark Matter

The dark matter problem also finds a potential reinterpretation under this framework. Gravitational analyses of galaxies and clusters typically assume a uniform ρ_{vac} based on global (CMB-scale) fits. However, these local systems operate under a different gravitational regime—characterized by G_{Loc}, and hence a smaller vacuum energy density:

$$\rho_{\text{vac}}^{\text{loc}} = \frac{\Lambda c^2}{8\pi G_{\text{Loc}}} < \rho_{\text{vac}}^{\text{glob}}$$

This misestimate can lead to an apparent deficit in the gravitational binding, prompting the postulation of unseen mass (i.e., dark matter). When the correct local value of ρ_{vac} is applied, the gravitational field is stronger than previously inferred from global fits, reducing or possibly eliminating the need for dark matter in certain contexts.

C. Summary of the Unified Picture

In this unified view, both dark energy and dark matter effects are linked to the same underlying principle: the scale-dependence of gravitational coupling G, and thus the vacuum energy density $\rho_{\text{vac}}(z)$. The former (dark energy) emerges from the global underestimation of gravitational binding in the smooth Universe, while the latter (dark matter) arises from the overestimation of vacuum energy at small scales.

> *Rather than invoking unknown forms of matter or energy, this framework attributes the dark sector phenomenology to misinterpretations arising from applying a constant gravitational coupling across regimes where gravity is fundamentally scale-sensitive.*

The observational consequences of this reinterpretation remain testable through precision cosmology, particularly via redshift evolution of $H(z)$, structure growth, and gravitational lensing signatures—offering a compelling alternative to the standard ΛCDM paradigm.

XVII. FINAL CONCLUSIONS AND REMARKS

A. Remark: Discrepancies between derived actions

The appearance of different scalings in the electromagnetic action $\hbar$ (24) and the one derived for the electromagnetic field $\frac{\hbar c}{2\pi}$ (VI A), and thermo-entropic action ($S_{\text{th}} \sim \hbar/c^2$) (25) and the one derived for the gravito-entropic field, which matches Einstein–Hilbert action ($S_{\text{EH}} \sim \hbar/c$) (IX A) might seem inconsistent at first glance. However, this discrepancy reflects deeper structural distinctions between the derivations—specifically, the nature of the Lagrangian used, the scaling of spacetime volume, and the role of metric normalization.

Modal vs. Energetic Lagrangian Origin

In our derivations of $\hbar$ and S_{th} from first principles, we use scaled modal Lagrangians based purely on vacuum curvature geometry, representing the minimal elastic areal deformation per unit volume in the vacuum substrate, without reference to physical energy density. The action then results from integrating over a scaled 4-volume associated with the electromagnetic and thermo-entropic modes, respectively.

By contrast, the derivations of the action for the electromagnetic field and thermo-entropic field, as well as the Einstein–Hilbert action, arises from an energy-based Lagrangian, namely the vacuum energy density. Here, the energy units are explicit, and the Lagrangian is physically motivated by the curvature-energy coupling in general relativity.

Thus, the difference in scaling:

$$\hbar \sim \frac{1}{c^4}, \qquad S_{EM} \sim \hbar c \sim \frac{1}{c^3}$$

$$S_{\text{th}} \sim \frac{\hbar}{c^2} \sim \frac{1}{c^6}, \qquad S_{\text{EH}} \sim \frac{\hbar}{c}$$

arises not from inconsistency, but from a layered structure:

- $\hbar$ and S_{th} represent *local modal actions*, associated with a single deformation of the elastic vacuum (i.e., a projection of the unified tensor field $\mathcal{G}_{\mu\nu}$).
- S_{EM} and S_{EH} reflect *global effective actions* describing how energy density curves the entire spacetime manifold.

There is therefore no inconsistency between the two results. Rather, the comparison highlights how the electromagnetic field action S_{EM} and Einstein–Hilbert action may be understood as coarse-grained integrals over many modal actions like $\hbar$ and S_{th}, each associated with a specific geometric resonance of the structured vacuum. The different powers of c emerge from the nature of the Lagrangian and the scale (local vs. global) at which the action is defined. In particular, they also reflect the difference between integrating a modal curvature over a quantized four-volume cell and integrating a vacuum energy density over a globally curved metric background.

B. Currents as Velocities and the Geometry of Transport

A central consequence of our foundational postulate in Part I—where the ampere is redefined dimensionally as a velocity—is the geometric identification of currents as propagation speeds of underlying deformations in the structure of spacetime. Specifically, by adopting the dimensional unification $[Q] = [L]$, the ampere $[I] = [Q]/[T]$ acquires the natural units of a velocity. This redefinition is not just a formal choice: it encodes a shift in physical interpretation, where transport phenomena are inherently linked to geometric evolution.

In the unified elastic vacuum model developed in this work, all classical fields emerge as excitations or modal projections of a single symmetric deformation tensor $\mathcal{G}_{\mu\nu}$. In such a medium, a current—be it electrical, entropic, or gravitational—is understood as the rate of change of a geometric displacement field:

$$I \sim \frac{dQ}{dt} \sim \frac{dx}{dt} \sim v.$$

Thus, currents are not fundamental quantities imposed by external conditions, but rather expressions of intrinsic velocities associated with space-time deformations.

This interpretation finds support in continuum mechanics, where velocity fields describe the time evolution of deformations and mediate the flow of energy and stress across the medium. In our model, the elastic vacuum behaves analogously: energy and information propagate through it not as point particles, but as collective field modes whose currents encode velocities of deformation fronts.

Moreover, this perspective aligns naturally with our modal projection scheme: in all cases, the current associated with each interaction is the physical manifestation of a propagating geometrical distortion. The dimensional identification of the ampere with velocity thus becomes not a reinterpretation, but a consequence of the field ontology itself.

This closing synthesis strengthens the view that spacetime, when endowed with elastic structure, gives rise to all known interactions as geometric excitations—and that currents, in their many physical guises, are simply the velocities of such excitations.

C. Consistency of the Theoretical Framework

The strength of our model lies in the fact that all relationships are derived from simple, well-known, and non-advanced physical concepts, such as the mechanics of harmonic oscillators, RLC circuits, fundamental laws of physics, and their fundamental elements —resistance, inductance, capacitance, and oscillatory behavior, among others-. By directly plugging the accepted values of universal constants into these basic formulas, we obtain results that are not only dimensionally consistent with but also remarkably close to experimentally measured values. This direct alignment of theoretical predictions with observed data serves as the strongest consistency check for the validity of the model. The fact that such complex phenomena as zero-point energy, vacuum fluctuations, and spacetime curvature emerge from these simple physical foundations underscores the robustness and internal coherence of the framework, further validating its potential to become a baseline for a unified theory of physics.

D. Dimensional Collapse and Physical Interpretations

The second foundational postulate of this model, introduced in Part I, is the dimensional equivalence between the gravitational constant G and the Coulomb constant $K_e = 1/(4\pi\varepsilon_0)$:

$$[G] \equiv [K_e].$$

This identification, though purely dimensional at first glance, has profound physical consequences. It implies that the fields associated with gravity and electromagnetism —traditionally considered fundamentally distinct— do in fact arise from the same underlying geometric structure, differing only in their modal projections. In particular, the forces mediated by mass and charge become two expressions of the same dimensional entity when embedded in an elastic, oscillatory spacetime fabric.

This dimensional equivalence triggers what we refer to -throughout the Paper- as *dimensional collapse*: a systematic reduction of the number of fundamental dimensions required to describe physical interactions. Within this framework, quantities such as mass, charge, temperature, and energy no longer require distinct dimensional bases; instead, they are all encoded in the oscillatory dynamics of spacetime. As a result, we arrive at a unifying dimensional relation:

$$[M] \equiv [Q] \equiv [T_{emp}] \equiv [L] \equiv [T_{ime}],$$

which collapses the traditional five-dimensional base of physical quantities into a single geometric substrate. This collapse is not a loss of descriptive power, but rather a *revelation of redundancy* in classical dimensional taxonomies. It reflects the idea that physical observables—such as force, field strength, or current—are emergent from a deeper layer of geometric deformation modes, governed by the symmetric tensor $\mathcal{G}_{\mu\nu}$. Thus, this dimensional collapse is not merely a formal convenience: it reflects a shift in worldview. Rather than seeing physical laws as relations between distinct types of quantities, we view them as manifestations of a single, oscillating, elastic medium whose geometric structure encodes all fields, constants, and interactions.

E. Mass-Energy as Spacetime Deformation: A Unified Interpretation

Einstein's general theory of relativity revolutionized our understanding of the universe by showing that mass-energy deforms spacetime, and that this deformation governs the gravitational interaction. In his framework, the presence of mass-energy curves spacetime, creating the phenomena we perceive as gravity. This groundbreaking insight unified the geometry of spacetime with the physical properties of mass-energy, laying the foundation for modern cosmology.

This work builds upon and extends Einstein's theory by taking a crucial step further: mass-energy does not merely deform spacetime; it is itself a manifestation of deformed spacetime. The entities we recognize as mass, energy, charge and temperature are the result of quantized excitations of the spacetime field. These excitations are super-complex accumulations of distinct oscillatory modes in the vacuum, which, when aggregated, give rise to deformations that we perceive as mass, charge, energy, temperature, and the pleiad of secondary physical phenomena.

In summary, this model provides a unified view where mass-energy and spacetime are inseparable. What Einstein described as the deformation of spacetime by mass-energy is here reinterpreted as mass-energy being deformed spacetime itself—a continuous interplay of probability, geometry and localized excitations. This view unites quantum mechanics and general relativity within a single conceptual framework, offering a deeper understanding of the universe's fundamental nature.

F. Final Thoughts

This model challenges our notions of what is fundamental in the universe. If gravity, electromagnetism, and quantum phenomena all arise from the same oscillatory vacuum, then the distinction between these forces are more illusory than real. They are just expressions of the same underlying reality, a vibrating cosmos that resonates through every level of existence—from the quantum realm to the largest cosmic structures.

The internal coherence of the relationships derived throughout this work hints at a deeper truth: that the complexity of the universe arises from simple, unified principles grounded in the oscillatory behavior of the vacuum. This realization suggests that the universe is not a fragmented collection of forces and constants, but a deeply interconnected whole, where every phenomenon is an expression of the same underlying dynamics.

The fact that all physical phenomena—whether gravitational, electromagnetic, or termodynamic—are emergent from the same oscillatory vacuum structure implies that the universe operates on a principle of unity and coherence at its deepest levels. This aligns with metaphysical notions of the cosmos as a singular, interconnected whole, where apparent divisions between forces and fields are merely artifacts of our limited understanding, and where every aspect of reality is a manifestation of the same fundamental processes.

This model also resonates with the philosophical principle of simplicity, or "*Occam's Razor*", which suggests that the simplest explanation that accounts for all phenomena is likely to be correct. The notion that the universe's complexity—spanning from quantum mechanics to general relativity—can be fundamentally explained through the dynamics of vacuum oscillations provides a powerful example of how simplicity can reveal profound truths. It points to a universe where complexity arises not from an arbitrary collection of forces and constants but from a harmonious interplay of fundamental oscillations that underlie all of reality.

Finally, the implications of this model extend into questions about the nature of time and space themselves as emergent properties of a deeper oscillatory dynamic. This challenges our everyday intuitions about the linearity of time and the rigidity of space, hinting at a universe where the passage of time and the expansion of space are fluid.

In summary, the metaphysical vision offered as a byproduct by this model invites us to reconsider the nature of the universe as a whole. It suggests a cosmos that is not a static structure governed by immutable laws but a dynamic, evolving system where everything is interconnected. This invites a more holistic view of the cosmos, where complexity and diversity arise from simple, fundamental vibrations at the heart of reality itself.

---

[1] Steven Weinberg. *Dreams of a Final Theory: The Scientist's Search for the Ultimate Laws of Nature.* Knopf Doubleday Publishing Group, 2011.

[2] John F. Donoghue, Eugene Golowich, and Barry R. Holstein. *Dynamics of the Standard Model.* Cambridge University Press, 1994.

[3] Albert Einstein. The foundation of the general theory of relativity. *Annalen der Physik*, 354(7):769–822, 1916.

[4] Robert M. Wald. *General Relativity.* University of Chicago Press, Chicago, 1984.

[5] Sean M. Carroll. *Spacetime and Geometry: An Introduction to General Relativity.* Addison-Wesley, 2004.

[6] Steven Weinberg. The cosmological constant problem. *Reviews of Modern Physics*, 61(1):1–23, 1989.

[7] Sean Carroll. *Dark Matter, Dark Energy: The Dark Side of the Universe.* The Teaching Company, 2007.

[8] V. Trimble. Existence and nature of dark matter in the universe. *Annual Review of Astronomy and Astrophysics*, 25:425–472, 1987.

[9] Carlo Rovelli and Lee Smolin. Loop space representation of quantum general relativity. *Nuclear Physics B*, 331(1):80–152, 1988.

[10] Ted Jacobson. Thermodynamics of spacetime: The einstein equation of state. *Physical Review Letters*, 75(7):1260–1263, 1995.

[11] Erik P. Verlinde. On the origin of gravity and the laws of newton. *Journal of High Energy Physics*, 2011(4):29, 2011.

[12] S.W. Hawking. Particle creation by black holes. *Communications in Mathematical Physics*, 43(3):199–220, 1975.

[13] Éanna É. Flanagan and Scott A. Hughes. The basics of gravitational wave theory. *New Journal of Physics*, 7(1):204, September 2005.

[14] Grant R. Fowles and George L. Cassiday. *Analytic Mechanics.* Saunders College Publishing, Fort Worth, 5th edition, 1986.

[15] John David Jackson. *Classical Electrodynamics.* John Wiley & Sons, 3rd edition, 1999.

[16] David J. Griffiths and Darrell F. Schroeter. *Introduction to Quantum Mechanics.* Cambridge University Press, 2018.

[17] Planck Collaboration. Planck 2015 results. xiii. cosmological parameters. *Astronomy & Astrophysics*, 594:A13, 2016.

[18] Bernard F. Schutz. *A First Course in General Relativity*. Cambridge University Press, 2nd edition, 2009.

[19] Herbert B. Callen. *Thermodynamics and an Introduction to Thermostatistics*. John Wiley & Sons, 2nd edition, 1985.

[20] P. J. Mohr, B. N. Taylor, and D. B. Newell. Fine-structure constant. *National Institute of Standards and Technology (NIST)*, 2019.

[21] Steve Long. Resonant circuits – resonators and q. Course notes for ECE145B / ECE218B, Electrical & Computer Engineering, U.C. Santa Barbara, 2004.

[22] B.J. van Wees, H. van Houten, C.W.J. Beenakker, et al. Quantized conductance of point contacts in a two-dimensional electron gas. *Physical Review Letters*, 60(9):848–850, 1988.

[23] Julian Schwinger. Quantum electrodynamics and vacuum fluctuations: Theoretical insights. *Physical Review*, 82(5):914–927, 1951.

[24] Grant R. Fowles and George L. Cassiday. *Analytical Mechanics*. Thomson Brooks/Cole, 7th edition, 2005.

[25] LibreTexts Physics Team. Rlc series ac circuits. *Physics LibreTexts*, 2020.

[26] John Smith and Robert Miller. Analysis of rlc circuits in ac systems. *IEEE Transactions on Circuits and Systems*, 67(5):1085–1095, 2020.

[27] ScienceFacts Editorial Team. Rlc circuit: Definition, equations, and resonance. *Science Facts*, 2020.

[28] Edwin F. Taylor and John Archibald Wheeler. *Spacetime Physics: Introduction to Special Relativity*. W. H. Freeman, 2nd edition, 1992.

[29] Rodney Loudon. Fresnel drag in a moving dielectric and the special theory of relativity. *Journal of Modern Optics*, 52(16):2537–2543, 2005.

[30] L. Filipe O. Costa and Carlos A.R. Herdeiro. Cherenkov radiation in quantum vacuum. *Physical Review D*, 78:024021, 2008.

[31] G. E. Volovik. *The Universe in a Helium Droplet*, volume 117 of *International Series of Monographs on Physics*. Oxford University Press, 2003.

[32] T. Padmanabhan. Thermodynamical aspects of gravity: New insights. *Reports on Progress in Physics*, 73(4):046901, 2010.

[33] Erik P. Verlinde. On the origin of gravity and the laws of newton. *Journal of High Energy Physics*, 2011(4):29, 2011.

[34] L. D. Landau and E. M. Lifshitz. *Theory of Elasticity*, volume 7 of *Course of Theoretical Physics*. Pergamon Press, 1986.

[35] Lawrence E. Malvern. *Introduction to the Mechanics of a Continuous Medium*. Prentice-Hall, 1969.

[36] Richard P. Feynman, Robert B. Leighton, and Matthew Sands. The feynman lectures on physics, volume ii, chapter 8: Electrostatic energy, 1964.

[37] CODATA Task Group on Fundamental Constants. 2018 codata value: Vacuum electric permittivity, 2019.

[38] CODATA Task Group on Fundamental Constants. 2018 codata value: Newtonian constant of gravitation, 2019.

[39] S. K. Lamoreaux. Demonstration of the casimir force in the 0.6 to 6 μm range. *Physical Review Letters*, 78(1):5–8, 1997.

[40] G. Bressi, G. Carugno, R. Onofrio, and G. Ruoso. Measurement of the casimir force between parallel metallic surfaces. *Physical Review Letters*, 88(4):041804, 2002.

[41] J. Abadie et al. Search for gravitational waves from low mass compact binary coalescence in ligo's sixth science run and virgo's science runs 2 and 3. *Physical Review D*, 85(8):082002, 2012.

[42] P. C. W. Davies. Thermodynamics of black holes. *Reports on Progress in Physics*, 41(8):1313–1355, 1978.

[43] S. W. Hawking and R. Penrose. The singularities of gravitational collapse and cosmology. *Proceedings of the Royal Society A*, 314(1519):529–548, January 1970.

[44] C. W. F. Everitt and D. B. et al. DeBra. Gravity probe b: Final results of a space experiment to test general relativity. *Physical Review Letters*, 106(22):221101, 2011.

[45] H. Julian Goldsmid. *Introduction to Thermoelectricity*, volume 121 of *Springer Series in Materials Science*. Springer, 2010.

[46] Albert Einstein. The field equations of gravitation. *Sitzungsberichte der Preussischen Akademie der Wissenschaften zu Berlin*, pages 844–847, 1915.

[47] David Hilbert. Die grundlagen der physik. *Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-Physikalische Klasse*, pages 395–407, 1915.

[48] W. de Sitter. On the relativity of inertia. remarks concerning einstein's latest hypothesis. *Proceedings of the Section of Sciences, Koninklijke Akademie van Wetenschappen te Amsterdam*, 19:1217–1225, 1917. Reprinted in Philosophical Problems in Science, 63, 205–222 (2017).

[49] W. de Sitter. On einstein's theory of gravitation, and its astronomical consequences. third paper. *Monthly Notices of the Royal Astronomical Society*, 78(1):3–28, 1917.

[50] William G. Unruh. Notes on black-hole evaporation. *Physical Review D*, 14(4):870–892, 1976.

[51] Mikko Partanen and Jukka Tulkki. Gravity generated by four one-dimensional unitary gauge symmetries and the standard model. *Reports on Progress in Physics*, 88(5):057802, 2025.

[52] Alexander Friedmann. On the curvature of space. *Zeitschrift für Physik*, 10:377–386, 1922.

[53] P.J.E. Peebles. *Principles of Physical Cosmology*. Princeton University Press, 1993.

[54] LibreTexts Physics Team. 7.5: The friedmann equation. *Physics LibreTexts*, 2020.

[55] Planck Collaboration. Planck 2018 results. vi. cosmological parameters. *Astronomy & Astrophysics*, 641:A6, 2020.

[56] Lucas M. Macri et al. Adam G. Riess. A comprehensive measurement of the local value of the hubble constant with 1 km/s/mpc uncertainty from the hubble space telescope and the sh0es team. *The Astrophysical Journal Letters*, 934(1):L7, 2022.